

# Super-Resolution for 2K/8K Television Using Wavelet-Based Image Registration

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### 1 Introduction

**8K UHD TV broadcasting**

- It is planned for launch in Japan in December 2018
- by using Broadcasting Satellite (BS).

**Display of 2K content with 8K system**

### 4 Overview of proposed method

### 7 Assignment

### 10 Experiment

Frequency power spectrum of an original 8K video frame and its reduced 2K video frame

This reduction was performed using pixel interleaving after low-pass filtering with the Lanczos-3 filter.

We confirmed that the shape of the frequency power spectrum of reduced 2K video frames are similar to their 8K video frames.

### 13 Result (SSIM)

SSIM values of the PM are 0.020~0.077 higher than the BC, MFR, SAR and DSW

Sequences		PM				
		BC	MFR	SAR	DSW	PM
Trains-B	Y	0.821	0.829	0.838	0.843	0.864
	C <sub>b</sub>	0.497	0.512	0.536	0.552	0.573
	C <sub>r</sub>	0.612	0.631	0.652	0.666	0.686
Japanese-Maple	Y	0.657	0.667	0.693	0.709	0.731
	C <sub>b</sub>	0.635	0.648	0.687	0.695	0.716
	C <sub>r</sub>	0.707	0.718	0.752	0.769	0.790
Umbrella	Y	0.682	0.701	0.720	0.737	0.758
	C <sub>b</sub>	0.419	0.440	0.469	0.482	0.503
	C <sub>r</sub>	0.555	0.578	0.617	0.632	0.652
Layered-Kimono	Y	0.340	0.357	0.368	0.374	0.395
	C <sub>b</sub>	0.308	0.322	0.343	0.348	0.369
	C <sub>r</sub>	0.361	0.375	0.392	0.401	0.421

Processing times of the PM are 2/3~1/256 lower than the MFR, SAR and DSW.

### 2 Related works

**Learning-based super-resolution**

- Example-based super-resolution
- Super-resolution convolutional neural network

**Reconstruction-based super-resolution**

- Filtering-based super-resolution
  - Linear filtering
  - Non-linear filtering
- Registration-based super-resolution
  - Multi-scale registration
  - Proposed method

Generate correct resolution-enhanced components: ○  
However, it requires an extensive database set and a large number of repeated operations is required.

Generate correct resolution-enhanced components: ✗  
Because they are linear or non-linear filtering in a single frame.

Generate correct resolution-enhanced components: ○  
If registration is precisely done with high accuracy.

### 5 Basic idea of super-resolution by registration of wavelet multi-scale components

Super-resolution by using similar objects in a frame

Super-resolution of small-sunflower:  
If an arbitrary block in the small-sunflower matches a position in low-frequency band of decomposed big-sunflower, coefficients of the same position in its high-frequency bands are assigned to the same block of unknown super-resolved high-frequency bands.

### 8 Assignment

Second level assignment with accuracy assessment:  
Y<sub>1</sub><sup>0</sup> and (2m<sub>1</sub>, 2n<sub>1</sub>)<sub>1</sub> are then expanded twice for horizontal and vertical directions as 2Y<sub>1</sub><sup>0</sup> and (2m<sub>1</sub>, 2n<sub>1</sub>)<sub>1</sub>. If the difference between 2Y<sub>1</sub><sup>0</sup> and the coefficients of position (2m<sub>1</sub>, 2n<sub>1</sub>)<sub>1</sub> in Y<sub>1</sub><sup>0</sup> is less than the threshold value T<sub>2</sub>, the coefficients of the same position (2m<sub>1</sub>, 2n<sub>1</sub>)<sub>1</sub> in high-frequency bands (Y<sub>10</sub><sup>0</sup>, Y<sub>20</sub><sup>0</sup>, Y<sub>40</sub><sup>0</sup>) are assigned to the same block of (Y<sub>10</sub><sup>1</sup>, Y<sub>20</sub><sup>1</sup>, Y<sub>40</sub><sup>1</sup>).

### 11 Experiment

**Super-resolution methods**

- Bi-cubic interpolation (BC)
- Multi-frame registration (MFR)
- Synthetic aperture radar (SAR)
- Discrete and stationary wavelet decomposition (DSW)
- Proposed method (PM)

**Parameters of proposed method**

- Wavelet : F<sub>10</sub> = 'CDF 9/7 wavelet'
- Decomposition level : n = 6
- Block size and search range : B<sub>0</sub> = (4, 6, 8), S<sub>0</sub> and S<sub>1</sub> = 2 × B<sub>0</sub>
- Threshold value : T<sub>1</sub> = B<sub>0</sub> × B<sub>0</sub> × 4

References: [MFR] S. C. Park, M. K. Park and M. O. Kang, "Super-resolution Image Reconstruction: A Technical Overview", IEEE Signal Processing Magazine, p. 21-36 (Mar. 2009). [SAR] S. Vitorra, M. Vega, D. Hahneman, R. Molero and A. Katsagoulas, "Bayesian combination of sparse and non sparse priors in single-frame resolution", Digital Signal Processing, vol. 23, no. 2, p. 150-161 (Mar. 2013). [DSW] D. Hahneman and A. Chhabra, "DSWAGE: Fast and Accurate Super-Resolution by Using Discrete and Stationary Wavelet Decomposition", IEEE Transactions on Image Processing, vol. 20, no. 1, p. 178-186 (Mar. 2011).

### 14 Result (Cut-off image)

The PM obviously produced sharper and clearer image than the BC.

If the alignment of the PM was performed using the exhaustive-search block matching method instead of step-search-like block matching, the PSNR and SSIM increased about 0.14 (dB) and 0.008, respectively. However the computational cost of the PM increased about 256 times.

The PM has high image quality and a good balance with the computational cost.

### 3 Problems

Super-resolution with high-quality for high enlargement

- Super-resolution of 2K/8K television needs enlarged 16 times.
- Extensive processing time

**Processing of the proposed method:**

- Registration of wavelet multi-scale bands
- Alignment by step-search-like block matching from an original 2K video frame to its low-frequency bands
- Assignment of two-level high-frequency bands with accuracy assessment

### 6 Alignment

Step-search-like block matching between an original 2K video frame and its decomposed low-frequency bands.

### 9 Experiment

Test video sequences

Spatial resolution of the 8K video frame was reduced to 2K pixels to measure the PSNR and SSIM values after super-resolution.

### 12 Result (PSNR)

PSNR values of the PM are 0.20~2.43 (dB) higher than the BC, MFR, SAR and DSW

Sequences		PM				
		BC	MFR	SAR	DSW	PM
Trains-B	Y	31.18	31.48	32.13	32.52	32.60
	C <sub>b</sub>	32.72	32.98	34.45	34.78	34.99
	C <sub>r</sub>	40.99	41.45	42.89	43.10	43.31
Japanese-Maple	Y	26.16	26.20	27.30	27.37	27.63
	C <sub>b</sub>	32.91	33.11	34.94	34.97	35.20
	C <sub>r</sub>	37.29	37.48	39.42	39.44	39.68
Umbrella	Y	29.02	29.90	30.13	30.30	30.55
	C <sub>b</sub>	29.40	30.58	31.30	31.47	31.68
	C <sub>r</sub>	40.00	41.37	42.04	42.21	42.43
Layered-Kimono	Y	34.97	35.38	35.99	36.04	36.27
	C <sub>b</sub>	33.85	34.03	35.88	35.90	36.10
	C <sub>r</sub>	41.66	41.90	43.64	43.70	43.90

Processing times of the PM are 2/3~1/256 lower than the MFR, SAR and DSW.

### 15 Conclusion

A super-resolution method for 2K/8K television

- Registration of wavelet multi-scale bands
- Alignment by step-search-like block matching from an original 2K video frame to its low-frequency bands
- Assignment of two-level high-frequency bands with accuracy assessment

The PM has high image quality and a good balance with the computational cost.

We are going to do hardware implementation of the PM.