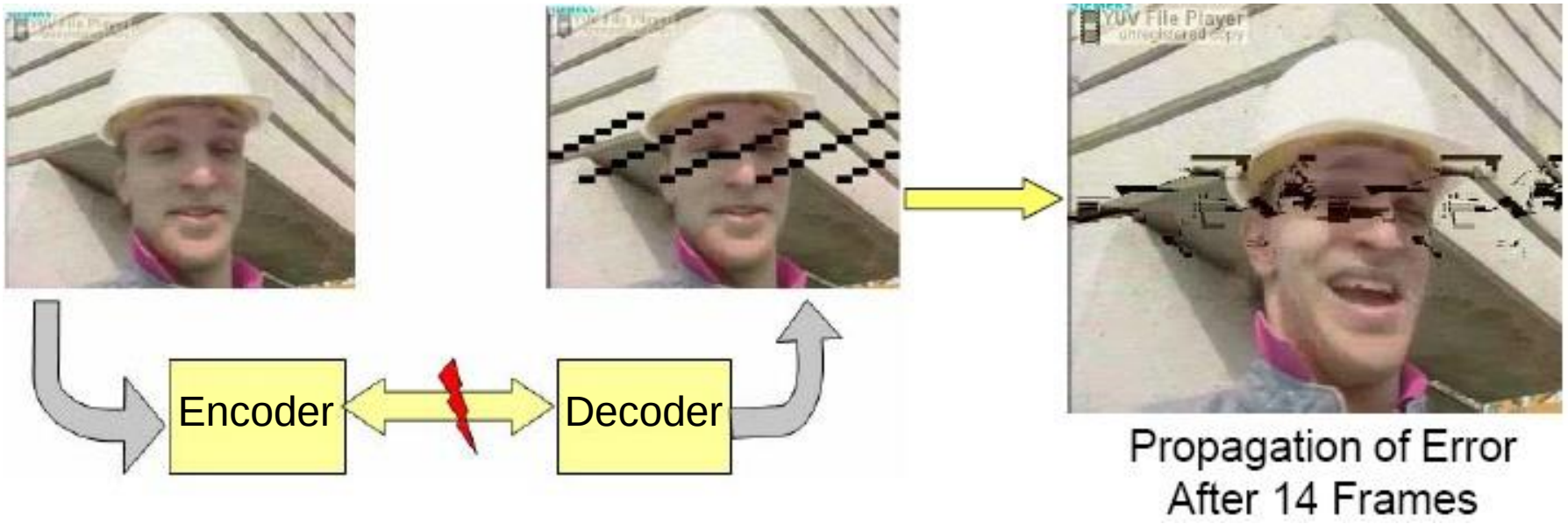
Low Complexity Error Concealment Scheme for Intra-frames in H.264/AVC

Santosh Chapaneri, Microsoft Corporation

Jeffrey Rodriguez, University of Arizona

Error Propagation

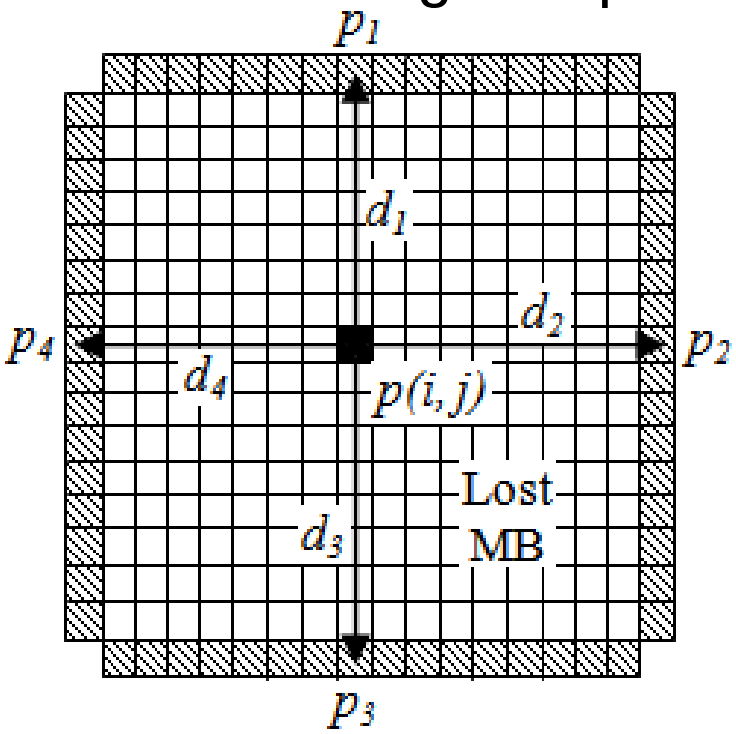


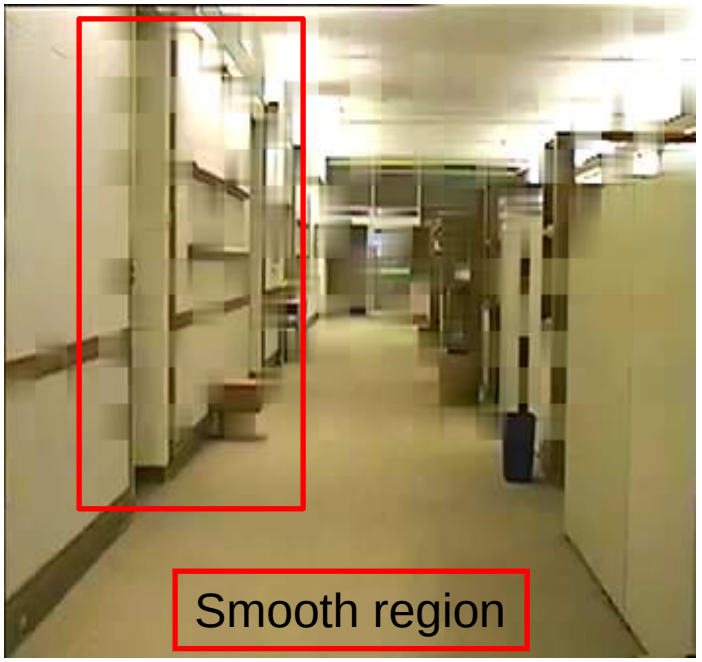
Transmission errors may result in loss of information, propagating over several frames of video sequence.

Goal: Estimate the lost information with some form of spatial interpolation in order to conceal the fact that an error has occurred

Error Concealment in H.264/AVC

- Based on weighted-pixel bilinear interpolation





- Performs well only when the missing MB (macroblock) is in a smooth region
- Creates blocking artifacts in the reconstructed picture
- Does not consider the edge directions

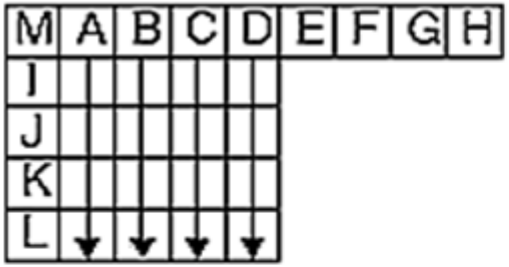
Proposed Spatial Algorithm: PMEC (Prediction Modes Error Concealment)

- H.264/AVC uses Intra prediction to reduce the spatial redundancies prior to transformation
- The prediction modes (*pmodes)* implicitly describe the edge orientations
- Use the existing information of *pmodes* of neighboring MBs to determine the dominant edge direction of the missing MB
- The proposed **prediction modes error concealment** (PMEC) algorithm has a reduced computational complexity

pmodes defined in H.264/AVC

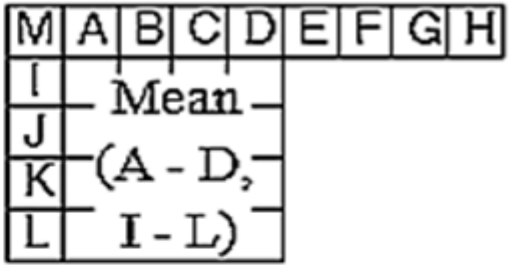
9 *pmodes* for 4×4 sub-block with directions from 0° to 157.5°

0 (vertical)

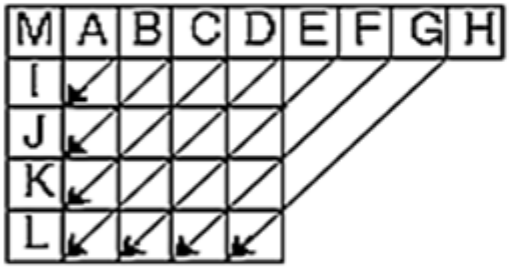


1 (horizontal)

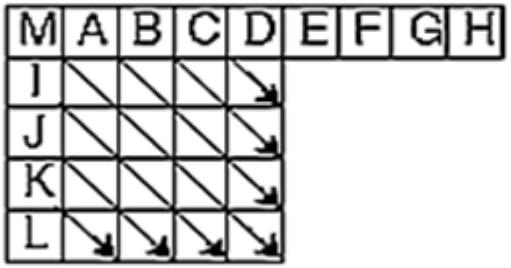
2 (DC)



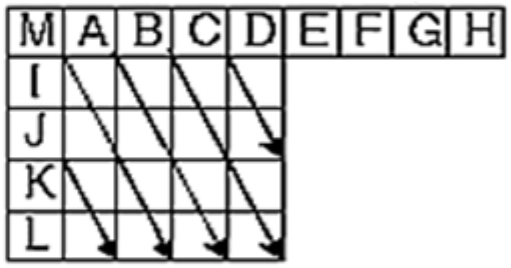
3 (diagonal down-left)



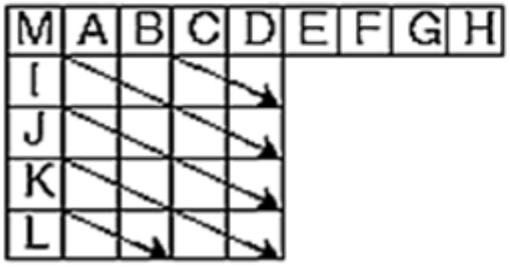
4 (diagonal down-right)



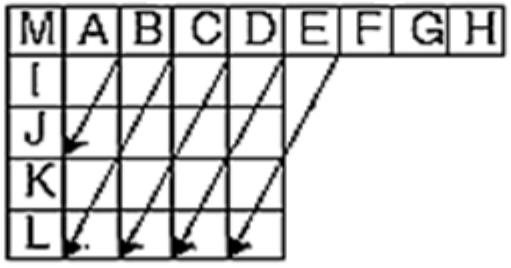
5 (vertical-right)



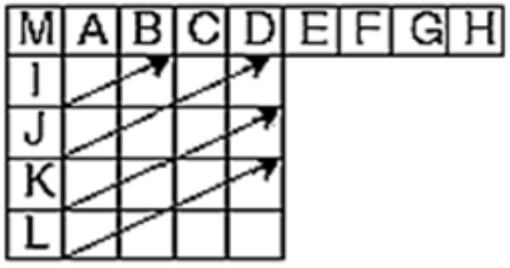
6 (horizontal-down)



7 (vertical-left)

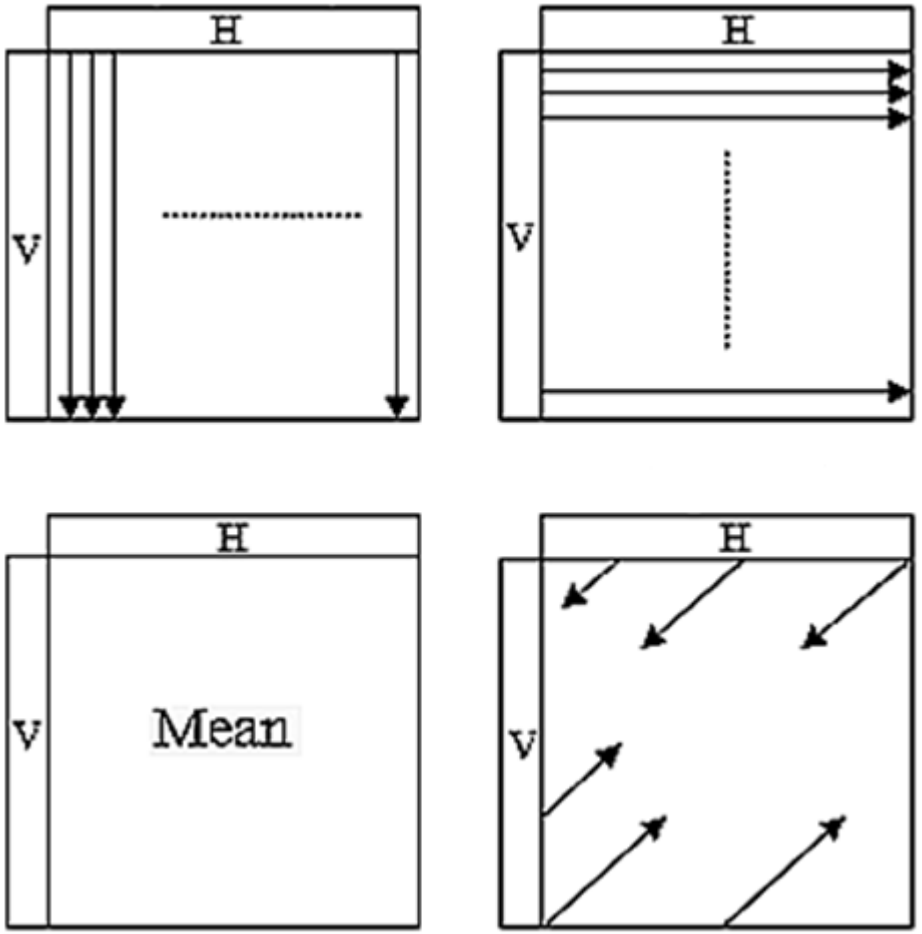


8 (horizontal-up)

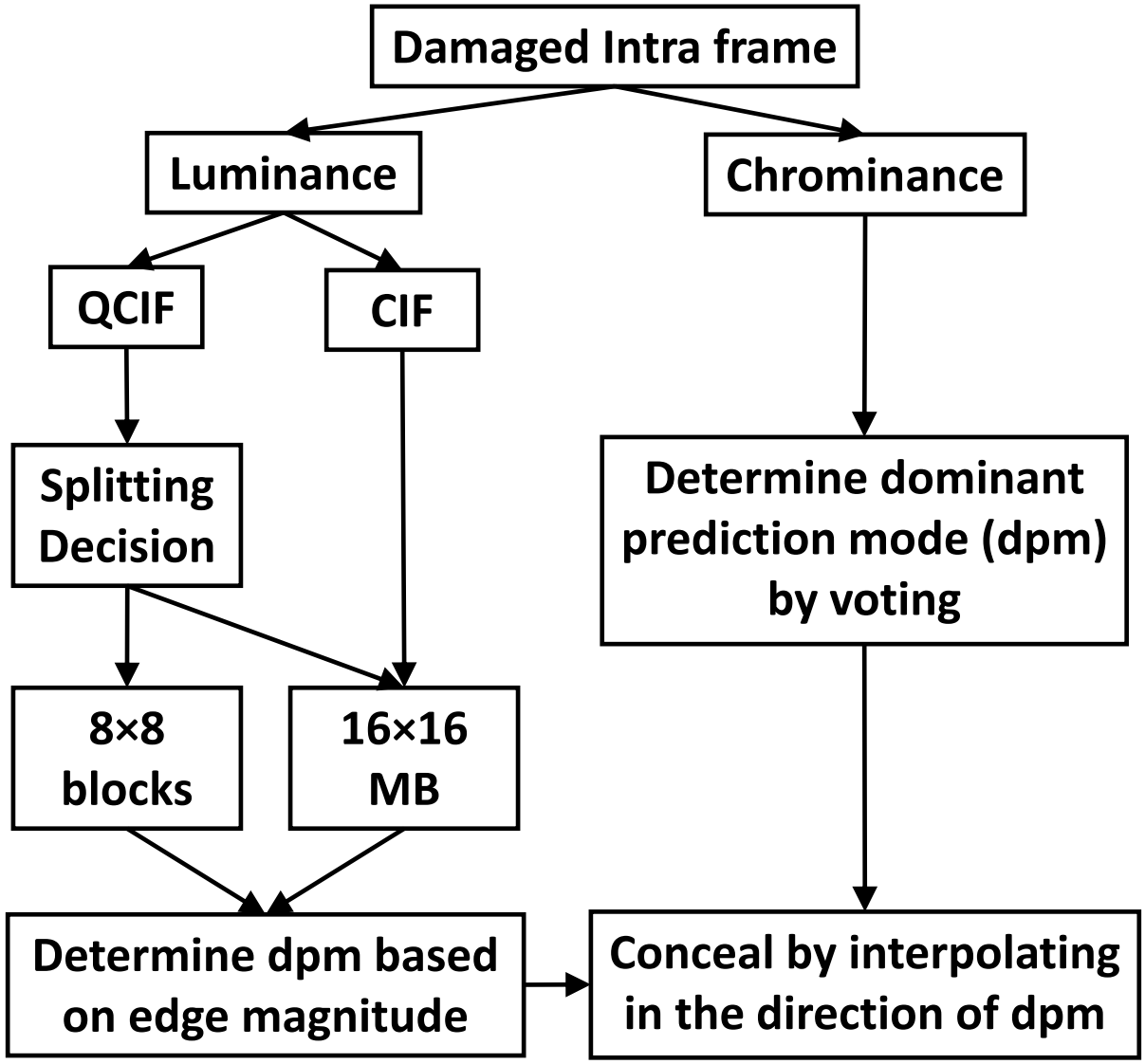


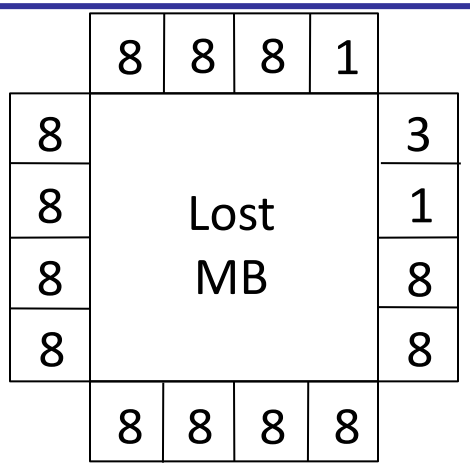
pmodes defined in H.264/AVC

4 *pmodes* for 16×16 MB with directions of 0°, 90°, and 45°

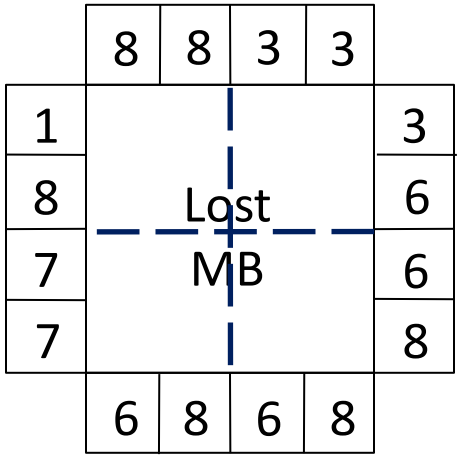


PMEC concepts



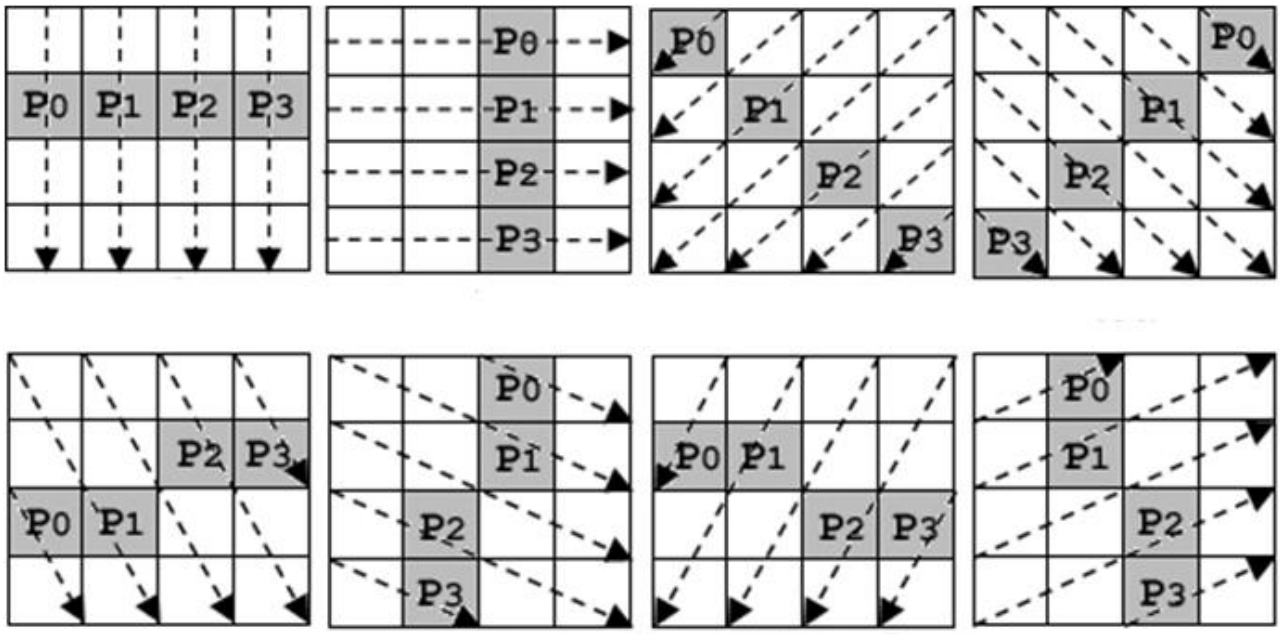


No splitting of lost MB



Split lost MB into 8x8 blocks

Dominant *pmode*



- **Edge magnitude** is estimated as **[max(P) – min(P)]*/d*** where P = {P_0, P_1, P_2 ,P_3} and *d* is the distance between max(P) and min(P)
- The dominant *pmode* is the one with the highest edge magnitude and concealment is performed in that direction

Computational Complexity of PMEC

Complexity for concealment of a 16×16 lost MB (256 pixels), considering all four neighboring MBs are available:

Operations	JM	Xu's method	PMEC
Additions	1536	1280+512*	**544**+512*
Multiplications	1024	640	**512**
Divisions	256	320	**272**
Comparisons	0	7	104
Shifts	0	0+512*	0+512*

*Extra computations for half-pixel boundary values when dpm = 5, 6, 7, or 8

JM = Joint Model reference software implementation of H.264/AVC
Xu's method = directional interpolation using Prewitt edge detector

PMEC Results

Foreman CIF Intra frame @ 10% loss rate

Concealed with Xu's method
PSNR = 33.17 dB, MSSIM = 0.8035

Concealed with PMEC
PSNR = 34.26 dB, MSSIM = 0.9126

(MSSIM: Mean Structural Similarity Index [0, 1])

PMEC Results: PSNR

Test Sequence	Error-free PSNR (dB)	Loss Rate	$PSNR_{JM}$ (dB)	$\Delta PSNR_{Xu}$ (dB)		$\Delta PSNR_{PMEC}$ (dB)	
				Mean	σ	Mean	σ
Carphone	37.9892	5%	35.1344	1.1504	0.0859	1.5715	0.1278
		10%	33.6031	0.2590	0.0448	0.6934	0.0503
		20%	31.7052	**0.7213**	0.0414	**1.2131**	0.0574
Foreman	36.4593	5%	34.0269	0.8296	0.0366	1.4390	0.0368
		10%	32.8493	0.8760	0.0389	1.2166	0.0350
		20%	30.7726	1.5135	0.0299	1.6729	0.0306
Table-tennis	35.6771	5%	35.2611	1.2200	0.0245	2.0912	0.0471
		10%	32.9875	**0.3618**	0.0302	**0.6436**	0.0345
		20%	31.3612	1.2404	0.0364	1.4864	0.0357
Suzie	37.7859	5%	35.2952	0.7688	0.0321	1.4503	0.0215
		10%	31.4557	1.4241	0.0256	1.7187	0.0262
		20%	30.2463	1.5994	0.0280	2.0819	0.0526
Stefan	36.4337	5%	33.2413	0.6696	0.0358	1.5909	0.0421
		10%	31.3147	0.8286	0.0362	1.9325	0.0234
		20%	30.9694	0.4357	0.0266	0.9832	0.0588
Hall	38.4136	5%	34.4084	**1.5218**	0.0349	**2.2568**	0.0527
		10%	32.9773	0.7444	0.0420	0.9986	0.0497
		20%	31.8247	0.6813	0.0336	1.1543	0.0234

Max. Improvement: 0.92 dB relative to Xu's method and 2.25 dB relative to JM

PMEC Results: MSSIM

Test Sequence	Error-free MSSIM	Loss Rate	$MSSIM_{JM}$	$\Delta MSSIM_{Xu}$		$\Delta MSSIM_{PMEC}$	
				Mean	σ	Mean	σ
Carphone	0.9731	5%	0.7281	0.0870	0.0031	0.1165	0.0037
		10%	0.5925	0.1533	0.0257	0.1880	0.0344
		20%	0.4712	**0.1573**	0.0177	**0.2402**	0.0175
Foreman	0.9608	5%	0.8192	0.1201	0.0055	0.1405	0.0063
		10%	0.6314	0.2421	0.0246	0.2751	0.0033
		20%	0.4827	0.2557	0.0038	0.3580	0.0196
Table-tennis	0.9133	5%	0.7273	0.1399	0.0246	0.1823	0.0037
		10%	0.6386	**0.1546**	0.0042	**0.2078**	0.0065
		20%	0.5499	0.1918	0.0037	0.2613	0.0057
Suzie	0.9657	5%	0.8135	0.1116	0.0060	0.1423	0.0028
		10%	0.6382	0.1429	0.0033	0.1949	0.0049
		20%	0.5367	0.2060	0.0043	0.2772	0.0041
Stefan	0.9793	5%	0.7032	**0.1151**	0.0059	**0.1821**	0.0038
		10%	0.5387	0.1918	0.0043	0.2378	0.0042
		20%	0.3826	0.3138	0.0039	0.3703	0.0056
Hall	0.9556	5%	0.8164	0.0908	0.0029	0.1330	0.0033
		10%	0.6928	0.1226	0.0036	0.1543	0.0028
		20%	0.6171	0.2053	0.0047	0.2836	0.0030

Max. Improvement: 0.1 relative to Xu's method and 0.37 relative to JM