Ming Hsieh Department of Electrical Engineering

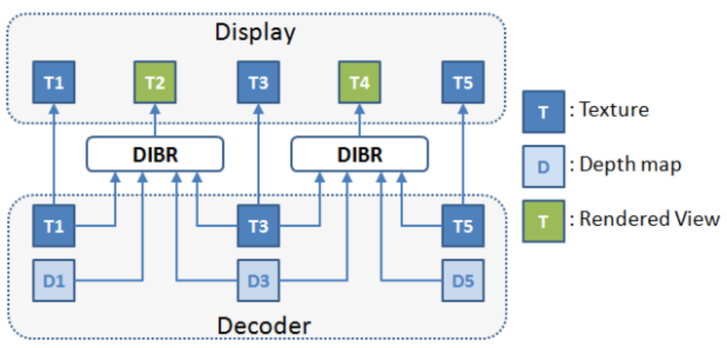
A New In-Loop Filter for Depth Map Coding in HEVC

USC Viterbi School of Engineering

Hyunsuk Ko and C.-C. Jay Kuo
Ming Hsieh Department of Electrical Engineering / Media Communications Lab

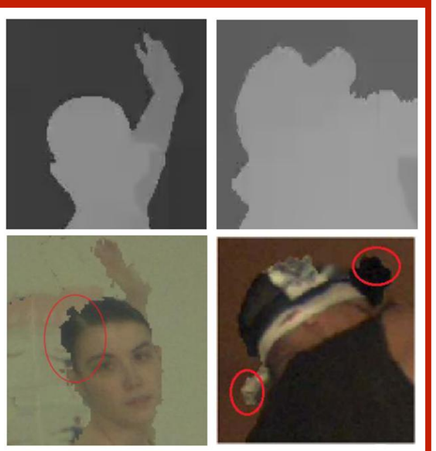
Depthmap in MVD based 3DVC

- Used to synthesize Virtual Texture Views using DIBR technique
- Main objective of Depthmap Coding
  1. To compress the depth data efficiently
  2. Ensuring the **quality of a synthesized view** is sufficiently high



Challenge in Depthmap Coding

- Characteristics of Depthmap Image
  1. Consists of **piecewise linear segments** bounded by strong edges
  2. Depth discontinuities represent disparity changes
- Challenge of Depthmap Coding
  1. The Object boundaries are very **sensitive to compress error**
  2. Severely affect **the Subjective quality of the Synthesized view**
- Blocking artifact resulting from block partitioning
  - Introduces unexpected "false" contours
- Blurring and ringing artifacts around sharp edges in a depth map
  - Introduce corrupted or growing edges



The visual artifacts in synthesized views

"Need a Depth Boundary Filtering!"

Problem of Conventional Approaches

- Recover object boundaries from its neighboring pixels using weighted averaging technique such as Bilateral / Trilateral filtering
- Introduce certain degree of blurring around edges
- As a result, introduce noticeable distortion in the rendered view such as disparity error

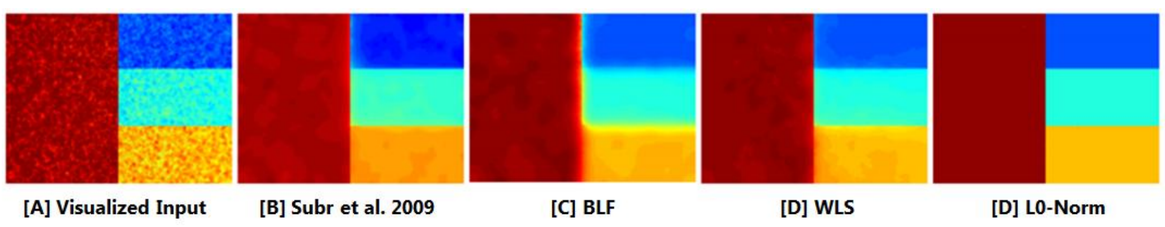
[De-blocking Filtering] [Bi-lateral Filtering]

L0-Norm based Depthmap Boundary Filtering

- Goal : **Maintain sharp edge** to ensure high quality of synthesized view → **L0-Norm based Filtering ***
- Advantages: Particularly effective for sharpening major edges by increasing the steepness of transition while eliminating a manageable degree of low-amplitude structures
  - ***I***: Input Image / ***S***: Its smoothed Image
  - Counting amplitude changes

$$C(S) = \#\{p \mid |\partial_x S_p| + |\partial_y S_p| \neq 0\}$$

  - The objective function $\min_S \left\{ \sum_p (S_p - I_p)^2 + \lambda \cdot C(S) \right\}$
  - The overall shape is in line with the original one **because intensity change must arise along significant edges to reduce as much as possible the total energy**



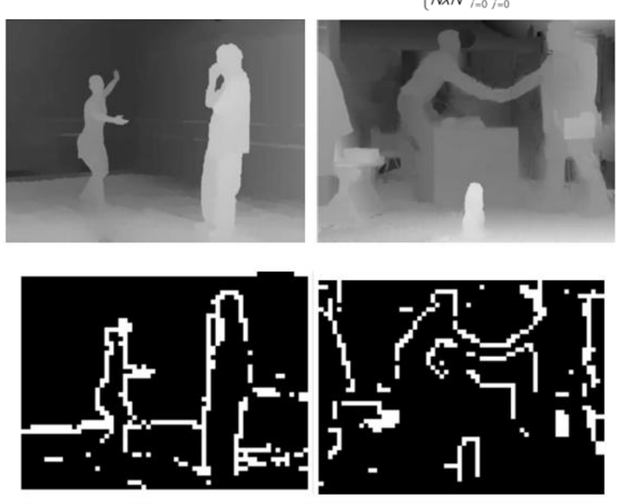
[A] Visualized Input [B] Subr et al. 2009 [C] BLF [D] WLS [D] L0-Norm

[★] Li Xu, Cewu Lu, Yi Xu, Jiaya Jia, "Image Smoothing via L0 Gradient Minimization", *SIGGRAPH*, Dec 2011

New In-Loop Filter for Depthmap Coding in HEVC

1. Boundary Block Detection

- To avoid another blocking Artifact by L0-filtering
  - Use Region-based filtering
- Standard deviation of a block for detecting boundary blocks
  - Non-boundary blocks consist of Homogeneous pixel values and have a smaller variance
  - Thresholding Technique: $STD = Sqrt\left\{\frac{1}{NxN}\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}[I(i,j) - Mean_{blk}]^2\right\}$



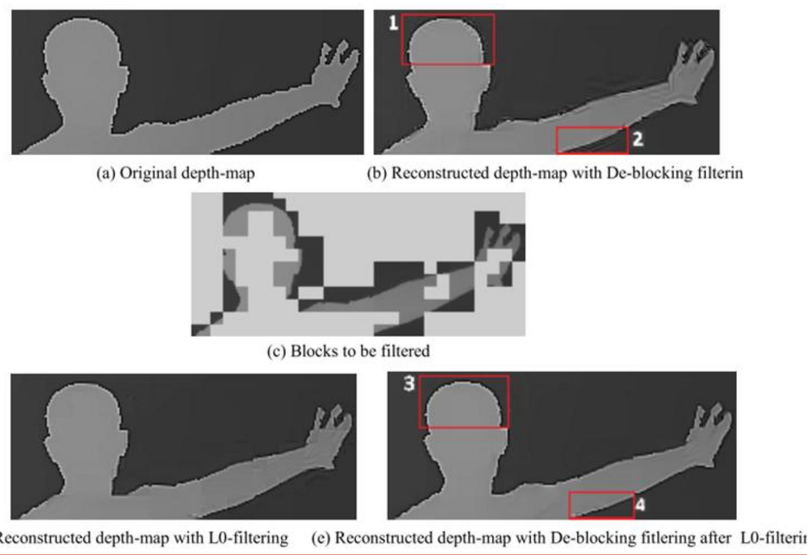
2. Quad-Tree Structure

- **Coding Unit (CU): Basic Coding Unit in HEVC**
  - Can be partitioned hierarchically using a **Quad-tree structure** to determine the best decomposition in terms of RD performance
  - Boundary Block: Encoded with variable block sizes
  - Homogeneous blocks: Encoded with a larger block size
- For the L0-filtering, use optimally decomposed Quad-Tree Structure
  - To avoid over/under filtering by considering the regional characteristics of a block

An example of LCU's Quad-tree structure The quad-tree based detection result

3. In-Loop Filtering

- In-loop filtering
  - Reduce the prediction residual by including the filtering process in the encoding loop
- We implement the In-loop filter by cascading the **L0-filter** and the **de-blocking filter**



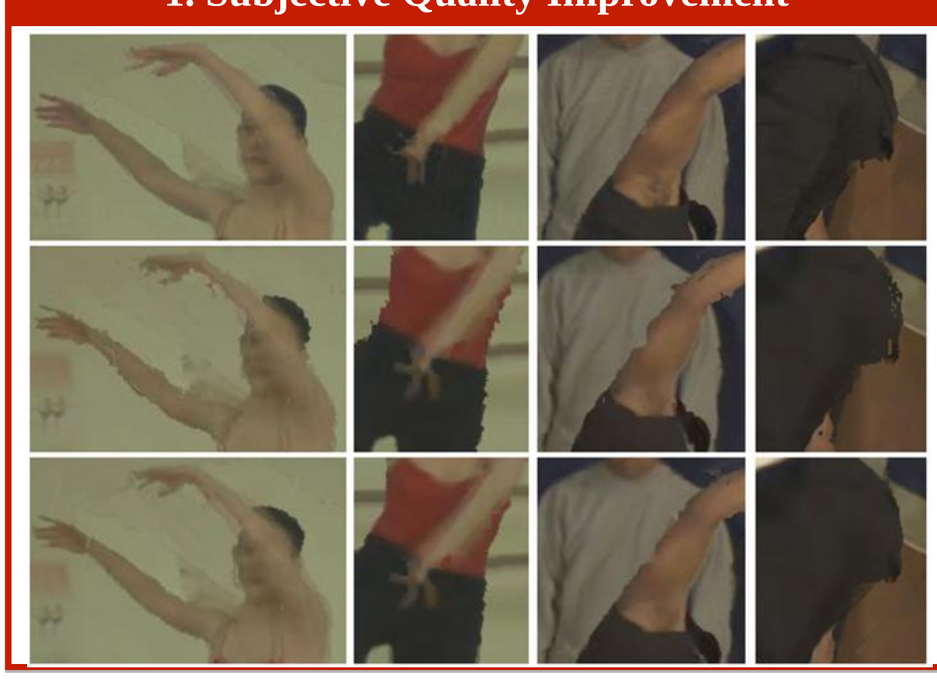
(a) Original depth-map (b) Reconstructed depth-map with De-blocking filterin

(c) Blocks to be filtered

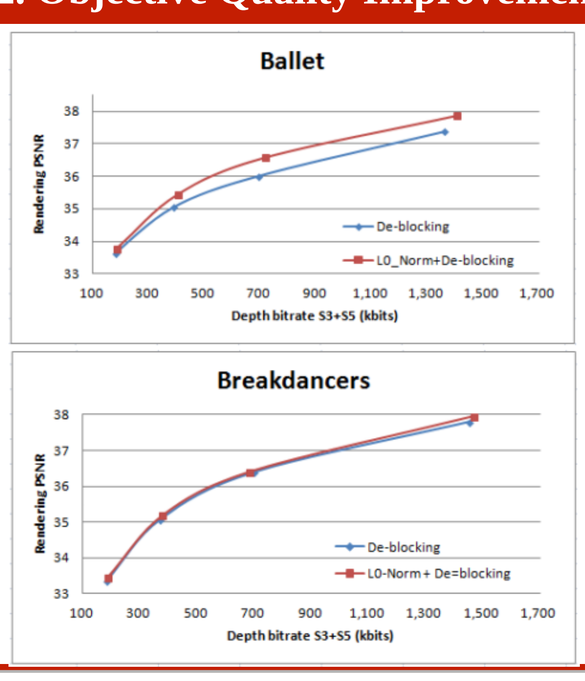
(d) Reconstructed depth-map with L0-filtering (e) Reconstructed depth-map with De-blocking fitlering after L0-filtering

Experimental Results

1. Subjective Quality Improvement



2. Objective Quality Improvement



3. Computational Complexity

	Encoding time of HM 5.0 (sec)	Encoding time of Proposed (sec)	Time Increase (%) $\left(\frac{column\_3}{column\_2} \times 100\right)$
Ballet (V3)	647	658	101.7
Ballet (V5)	638	651	102.0
Breakdancers (V3)	696	701	100.7
Breakdancers (V5)	693	704	101.6

Contact Info: kosu9980@gmail.com

Ming Hsieh Institute
Ming Hsieh Department of Electrical Engineering