BBAND Index: A No-Reference Banding Artifact Predictor

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Check out our paper #2805 here

Session: TH3.PJ: Perception and Quality Models (Thursday, 07 May, 16:30 - 18:30)

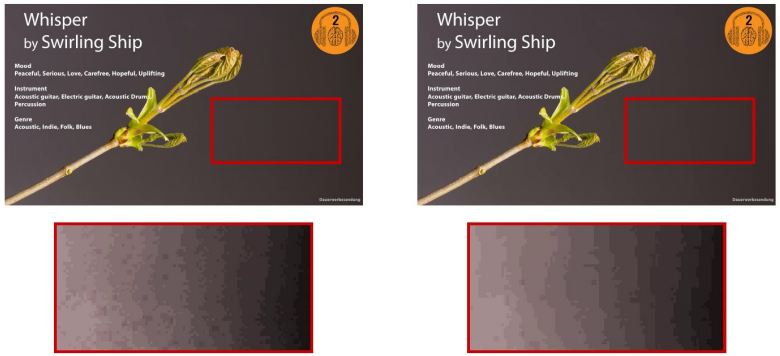
The University of Texas at Austin
LIVE
Laboratory for Image & Video Engineering

ICASSP2020
Barcelona

YouTube

Background: Banding Artifact

- A common compression artifact appearing in **flat regions** in encoded videos
- One of the dominant artifacts in **high-quality high-definition** videos
- Our goal is to design a **blind banding artifact detector (banding severity assessor)** for analyzing YouTube user-generated videos



(a) Original UGC (b) Transcoded/Re-encoded

Fig 1. An example of banding artifact exacerbated by VP9-transcoding

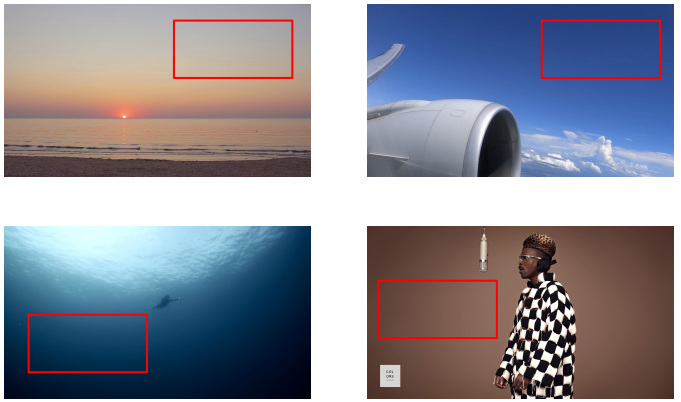


Fig 2. Exemplary content containing banding artifacts (SKY, SEA, WALL, BACKGROUND)

Related Works

- **Wang's method** [1]
  a. Unisegs generation
  b. Banding edge extraction
  c. Banding score evaluation

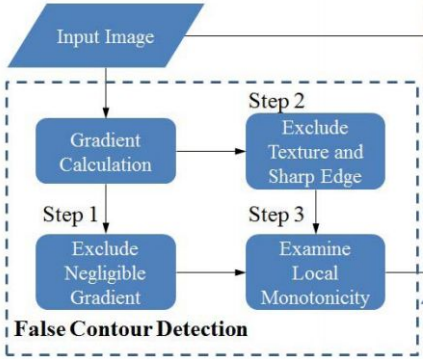


Fig 4. FCDR [2]

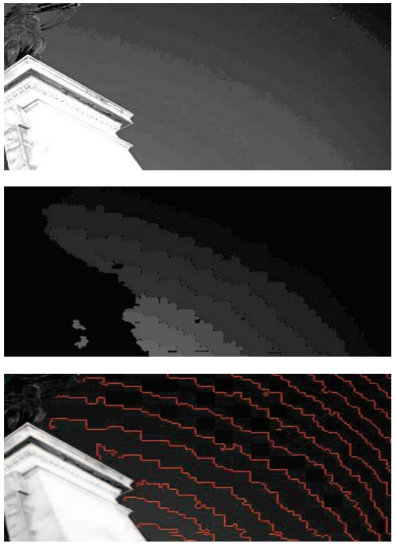
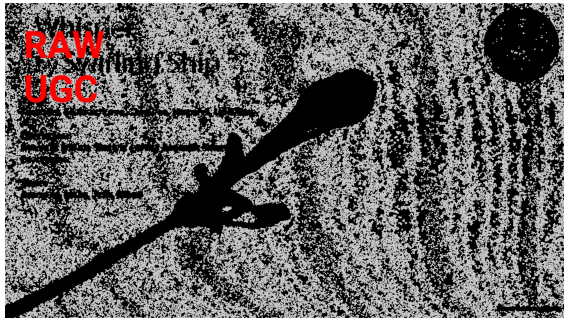


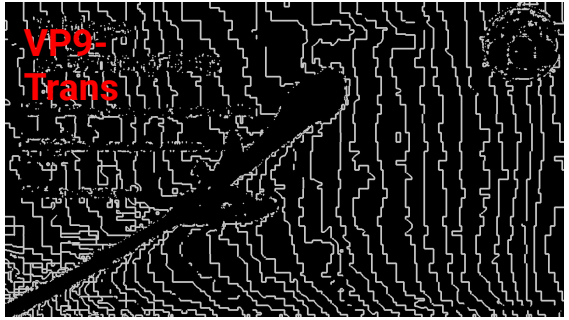
Fig 3. Wang's Method [1]

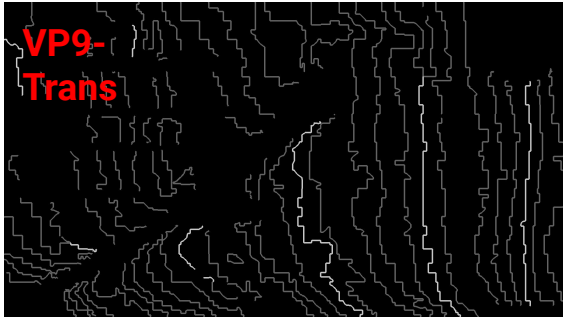
- **False contour detection and removal (FCDR)** [2]
  a. Calculate gradient map
  b. Exclude flat and textured areas by thresholding
  c. Exclude areas without gradient monotonicity

- [1] Wang, Yilin, et al. "A perceptual visibility metric for banding artifacts." *2016 IEEE International Conference on Image Processing (ICIP)*. IEEE, 2016.
- [2] Huang, Qin, et al. "Understanding and removal of false contour in hevc compressed images." *IEEE Transactions on Circuits and Systems for Video Technology* 28.2 (2018): 378-391.

Limitations of Existing Works







Test frame | **FCDR [2]** | **Wang's [1]**

- Unable to detect weak/noisy banding edges in raw UGC videos for **pre-processing** applications.

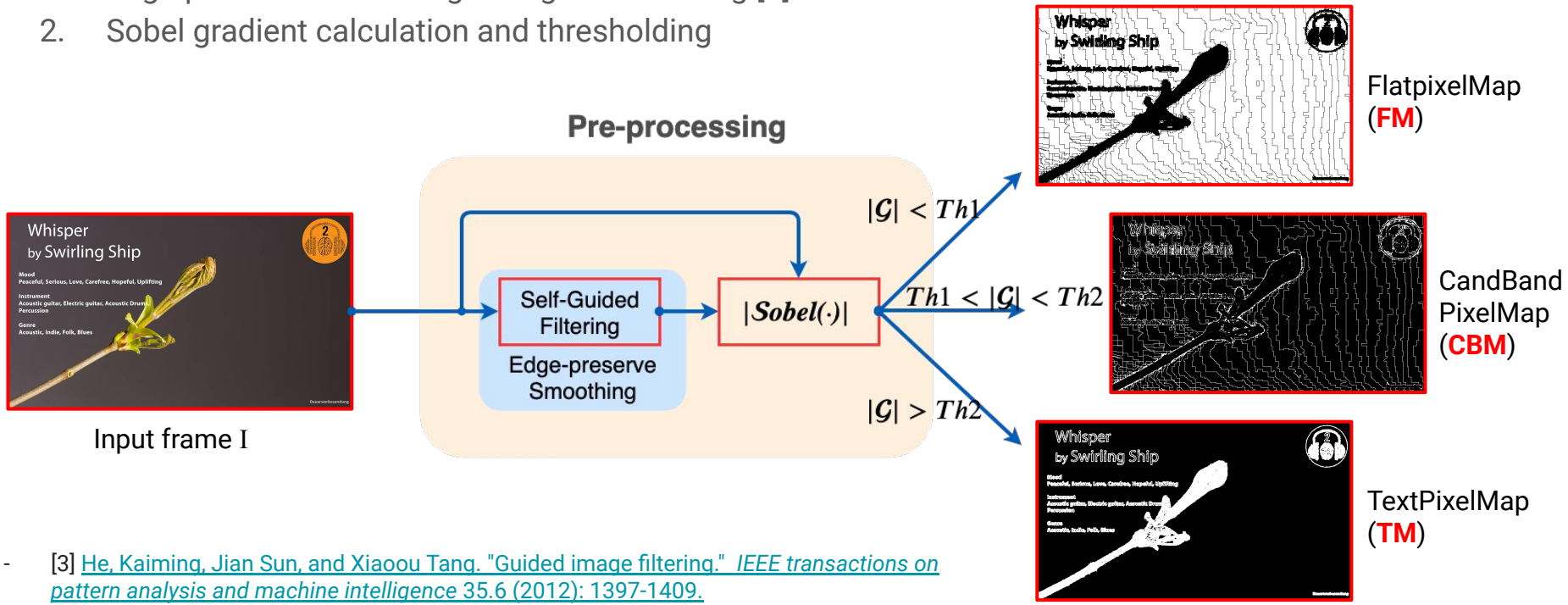
Proposed Banding Detector (BBAND Index/Algo)

- **Goals**
  - To build a robust blind banding detector applicable for both NOISY and CLEAN banding artifacts, which can yield banding edges as well as quality score consistent with human judgements. It can be used as a tool for both pre-processing and post-processing applications.

- **Proposed Blind Banding Artifact Detector (BBAND)**
  - Step1: Pre-processing + feature extraction
  - Step2: Banding edge extraction → **Output**: Banding Edge Map (BEM)
  - Step3: Banding visibility estimation → **Output**: Banding Visibility Map (BVM)
  - Step4: Spatial-temporal pooling → **Output**: Banding quality score

Step 1: Pre-Processing

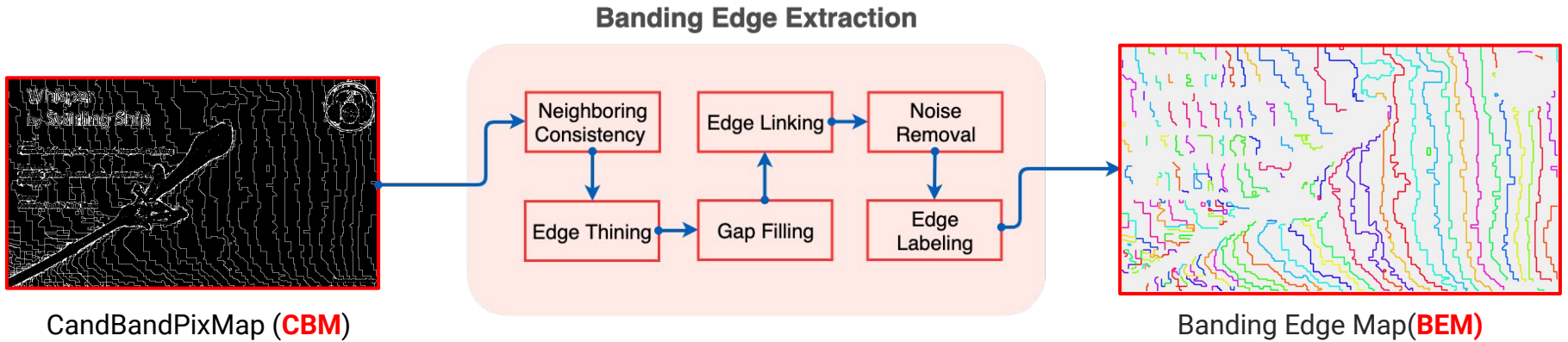
1. Edge-preserve smoothing: self-guided filtering [3]
2. Sobel gradient calculation and thresholding



- [3] He, Kaiming, Jian Sun, and Xiaoou Tang. "Guided image filtering." *IEEE transactions on pattern analysis and machine intelligence* 35.6 (2012): 1397-1409.

Step 2: Banding Edge Extraction

- **Inspired by Canny's Edge Detector**
  - Neighbor consistency: Banding pixel's neighbors must be Bandpixel or Flatpixel
  - Edge thinning: non-maxima suppression to ensure 1-pixel-width edge
  - Gap filling: to form the edges as long as possible
  - Edge Linking: link 8-connected neighbors
  - Noise removal: remove short edges below 16-pixel



CandBandPixMap (**CBM**)

Banding Edge Map(**BEM**)

Step 3: Banding Visibility Estimation

- **Why banding edges so visible?**
  - Mach bands effect [4]
    - Explained by Lateral Inhibition
- **Human visual systems (HVS)-inspired banding visibility estimation**
  - Basic feature
    - Edge contrast
  - Masking effects
    - Luminance masking
    - Texture masking
  - Edge length modulation
    - Inspired by Wang's method [1]

- [4] https://en.wikipedia.org/wiki/Mach_bands

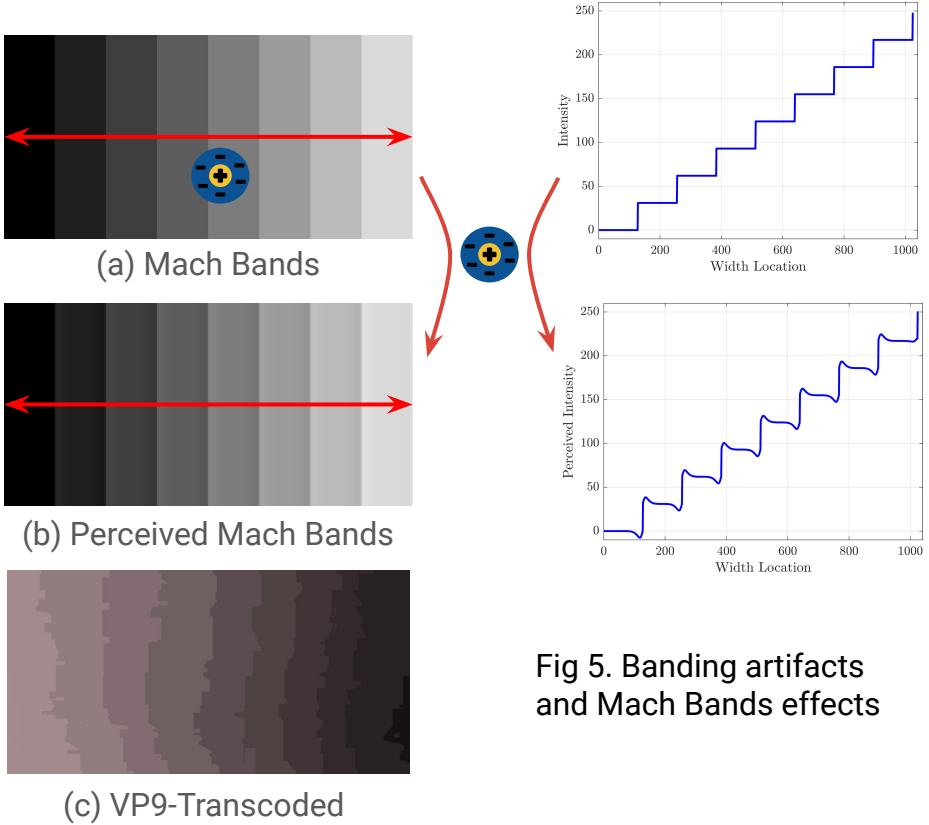
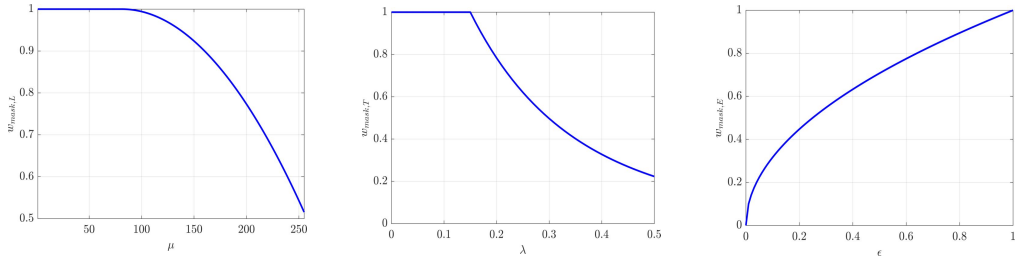


Fig 5. Banding artifacts and Mach Bands effects

Step 3: Banding Visibility Estimation (Cont'd)

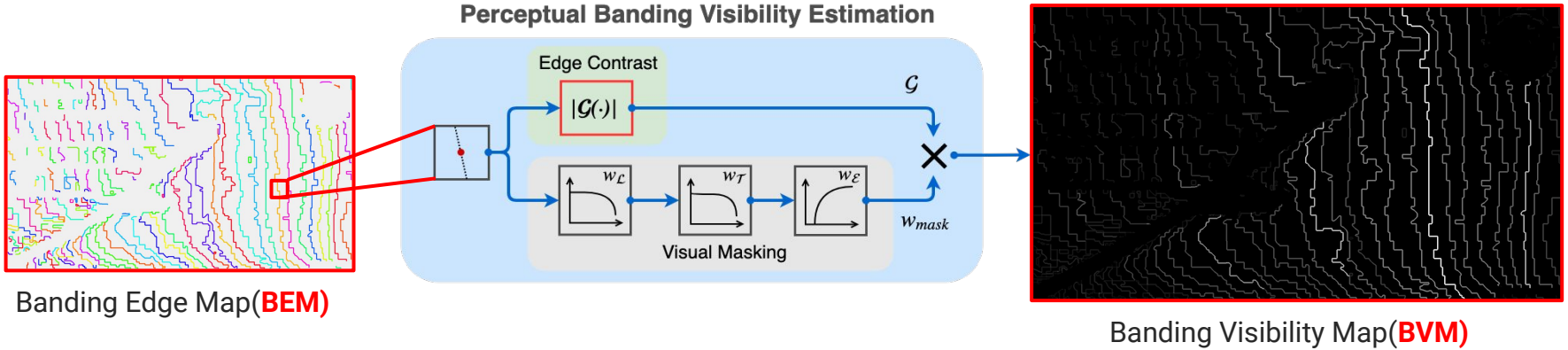
- **Visibility transfer function (VTF)**
  - Luma masking $\rightarrow w_l$
  - Texture masking $\rightarrow w_t$
  - Length masking $\rightarrow w_c$
- **Visibility Integration (point-wise):**

$$\mathrm{BVM}(i,j) = w_\ell(i,j) \cdot w_t(i,j) \cdot w_c(i,j) \cdot |\mathcal{G}(i,j)|$$



(a) Luminance Masking (b) Texture Masking (c) Edge Length Masking

Fig 6. Visibility Transform Function (VTF)



Banding Edge Map(**BEM**)

Banding Visibility Map(**BVM**)

Visual Results of Proposed Banding Detector

BBAND can:

- adaptively enhance/detect **weak banding edges** in **RAW UGC content** for pre-processing
- accurately **localize banding edges** for both pre-processing and post-processing quality enhancement.
- extract a **Human Visual System-based banding visibility map** to analyze video distortions

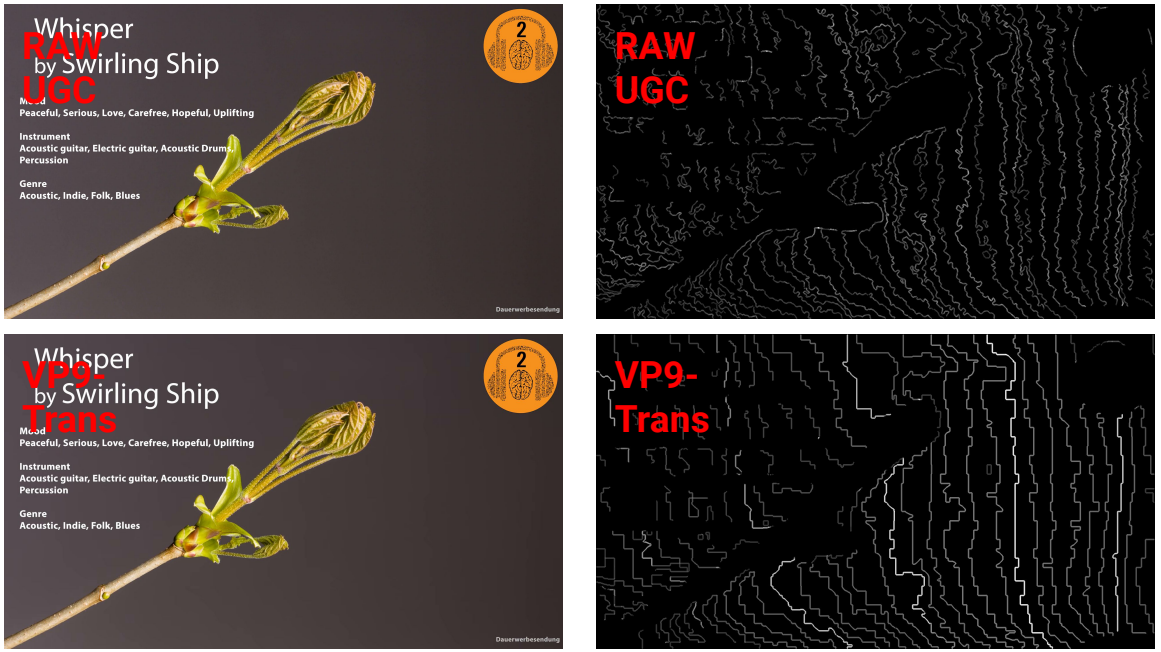


Fig 7. Visual results of proposed BBAND detector

Step 4: Spatial-Temporal Quality Pooling

- **Spatial visual importance pooling**
  - 80%-percentile pooling of BVM

- **Spatial-temporal pooling**
  - Banding occurs in non-salient regions
  - Spatial complexity and large motion will distract the attention on banding artifacts
  - Visibility tranfer function (VTF) of SI and TI
    - $\mathrm{SI} \rightarrow w_{SI}$, $\mathrm{TI} \rightarrow w_{TI}$
  - Frame-level banding quality:

$$\mathrm{Q}_{\mathrm{BBAND}_{\mathcal{I}}}(\mathcal{I}) = w_{\mathrm{SI}}(\mathrm{SI}) \cdot \frac{1}{|\mathcal{K}_{p\%}|} \sum\nolimits_{(i,j)\in\mathcal{K}_{p\%}} \mathrm{BVM}_{\mathcal{I}}(i,j)$$

  - Video-level banding quality:

$$\mathrm{Q}_{\mathrm{BBAND}_{\mathcal{V}}}(\mathcal{V}) = \frac{1}{N} \sum\nolimits_{n=1}^{N} w_{\mathrm{TI}}(\mathrm{TI}_n) \cdot \mathrm{Q}_{\mathrm{BBAND}_{\mathcal{I}}}(\mathcal{I}_n)$$

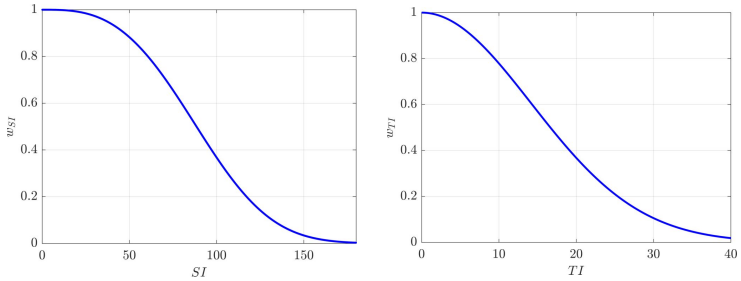


Fig 8. Visibility tranfer function for SI and TI

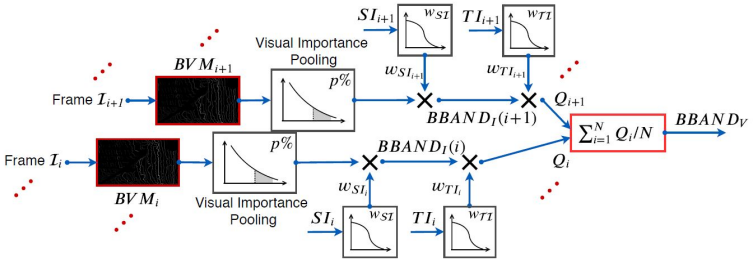


Fig 9. Flowchart of the spatial-temporal pooling framework

Subjective Evaluation of Banding Metrics

- **Dataset**: banding dataset with subjective scores proposed in Wang's paper [1]
- **Criteria**: Spearman rank (SRCC), Kendall rank (KRCC), Pearson Linear (PLCC), RMSE
- **Results**:

Metric	SRCC	KRCC	PLCC	RMSE
Baugh [16]	0.7739	0.6304	0.8037	9.7671
Wang [11]	0.8689	0.6788	0.8770	7.8863
BBAND	**0.9330**	**0.8116**	**0.9578**	**4.7173**

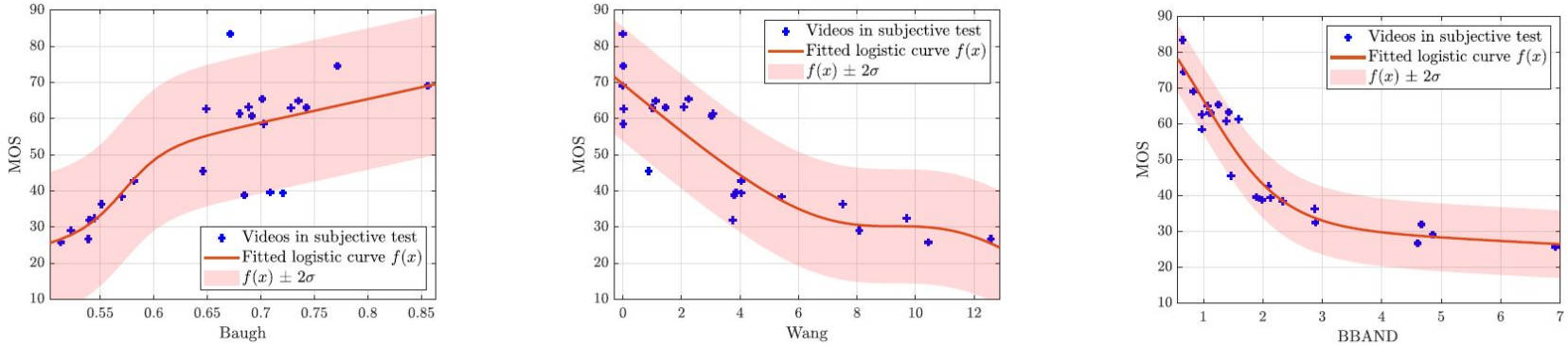


Fig 10. Scatter plots and regression curves of (a) Baugh [5], (b) Wang's [1], and (c) BBAND, versus MOS

- [5] Baugh, Gary, Anil Kokaram, and François Pitié. "Advanced video debanding." Proceedings of the 11th European Conference on Visual Media Production. ACM, 2014.

Summary and Future Works

- **Summary**: proposed a **blind perceptual banding artifact predictor** which can
  - **extract banding edges** for both **raw** and **transcoded** user-generated videos
  - **estimate banding visibility at pixel precision** based on a **human visual model (HVS)**
  - **predict both frame- and video-level banding quality score** which is highly consistent with human judgements

- **Future works**
  - Improve the proposed method by integrating **temporal features**
  - Apply banding detector to UGC **pre-processing analysis**
  - Apply banding detector to UGC **post-processing debanding filter**

Thanks for listening!

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