Understanding Banding - Perceptual Modelling and Machine Learning Approaches for Banding Detection

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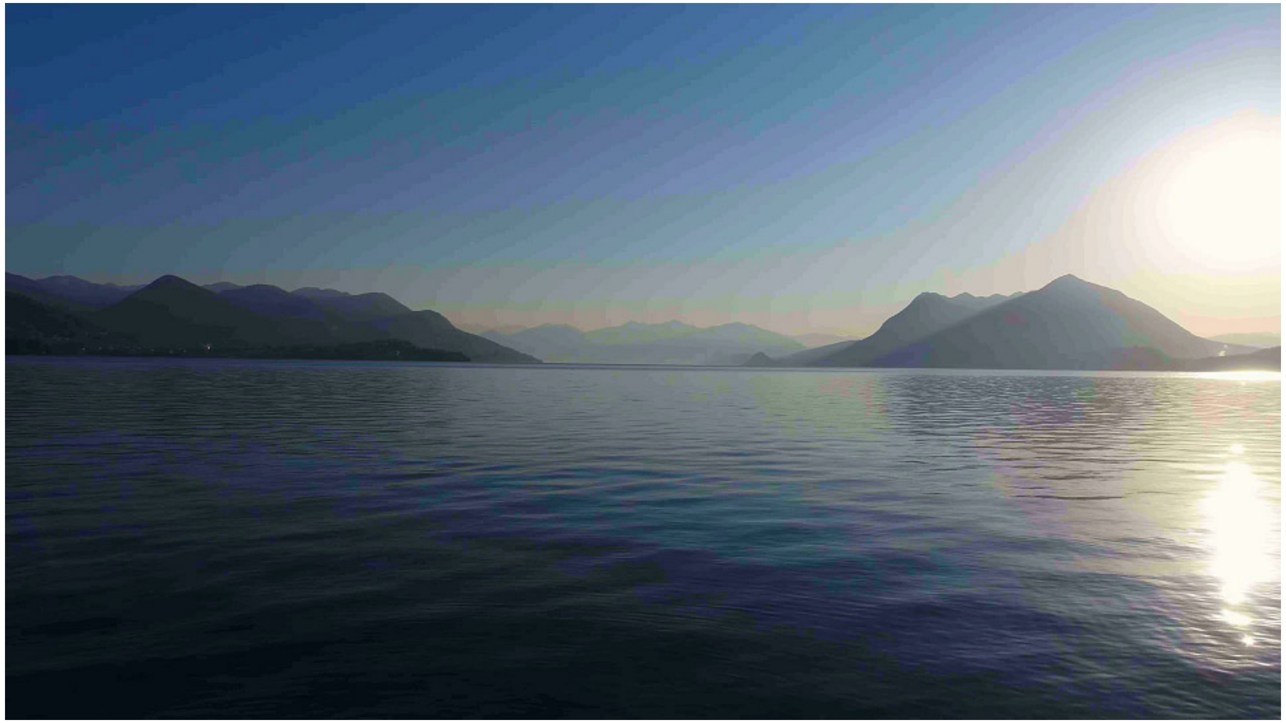
Agenda

- What is banding impairment?
- Knowledge-driven method to detect banding
- Data-driven based framework to detect banding
- Challenges
- Conclusion

What is banding impairment?

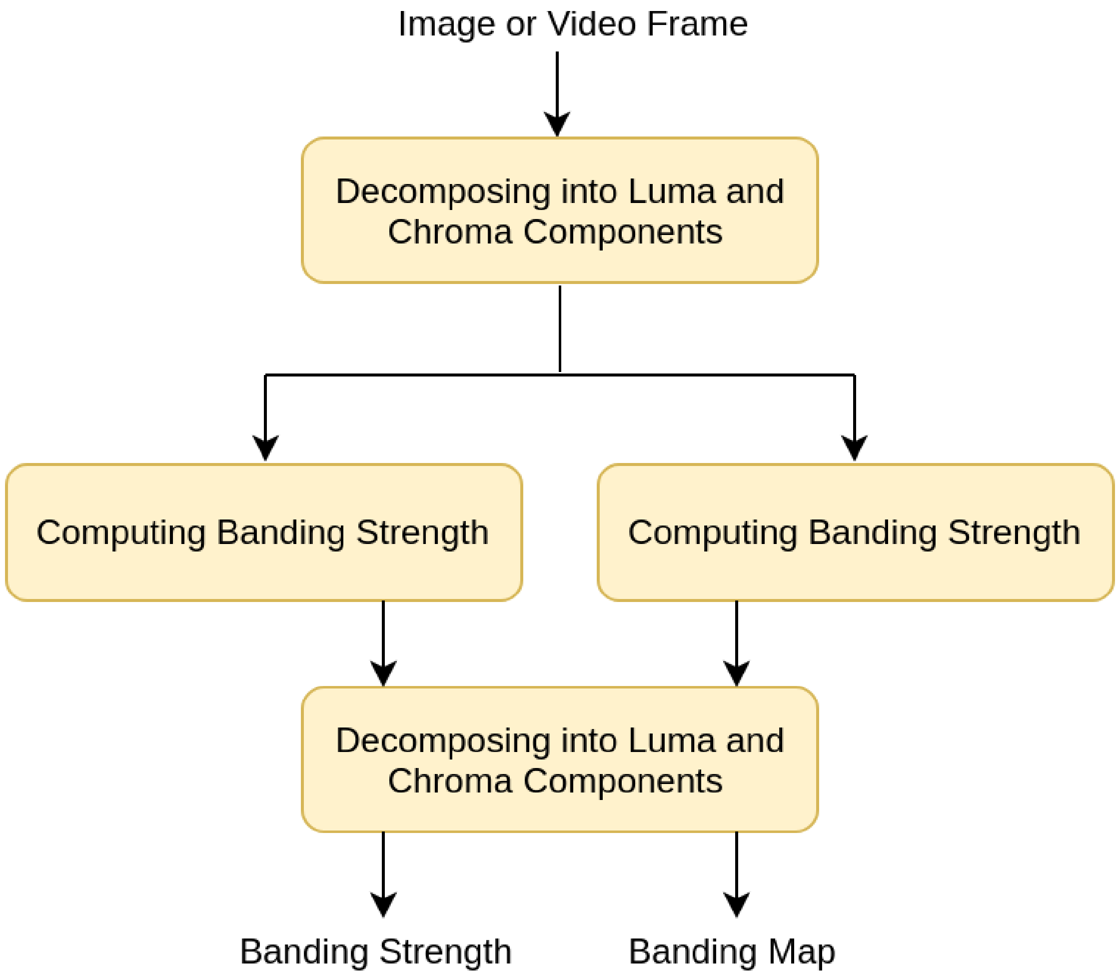
- Banding typically appears as perceived discontinuities or false contours in large and smooth image regions of slow color or intensity gradients

- Although heavy video compression is a potential source of banding, banding may also occur in the absence of any lossy compression, and may create annoying visual quality degradations in otherwise pristine quality images or video content



Knowledge-driven method to detect banding

- A knowledge-driven method is illustrated here, where the input is an image or a video frame at the pixel level, and the outputs are a banding score together with a banding map.
- The spread of banding impairment impacts viewing experience but does not solely represent banding annoyance
- The severity of banding is captured by the banding strength component
- The banding score denotes the overall level of perceived banding by considering banding spread and banding strength



Knowledge-driven method to detect banding

- Pixels that correspond to abrupt activities deemed visible as banding are then marked, which collectively constitute a banding map of the image or video frame. The banding map illustrates the presence of banding impairment in an image or a video frame, and does not reflect the banding strength

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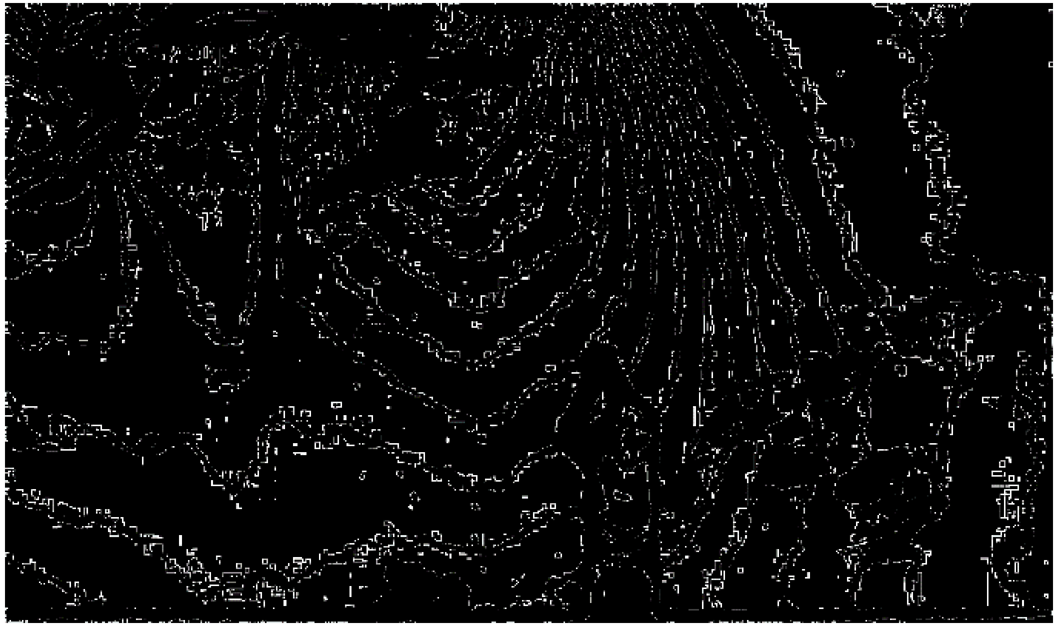
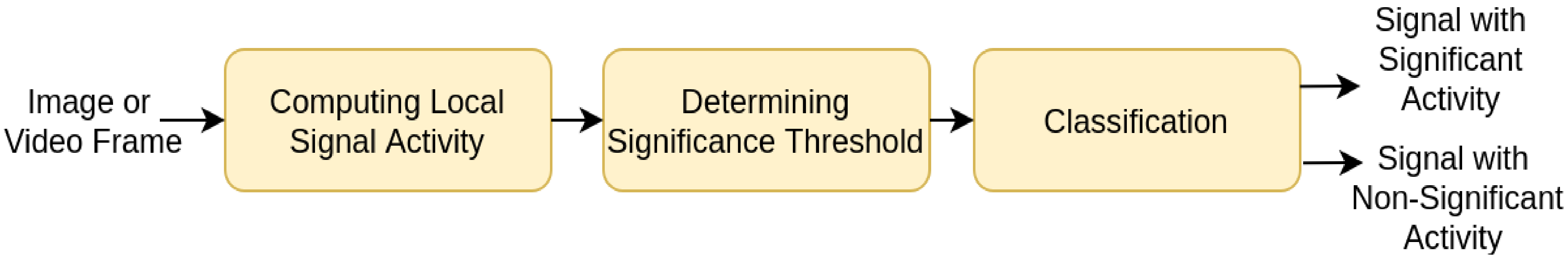


Knowledge-driven method to detect banding

- Banding regions may be determined by pixels in the image or video frame that have significant local signal activity while the signal activity in a majority of its surrounding regions is not significant.

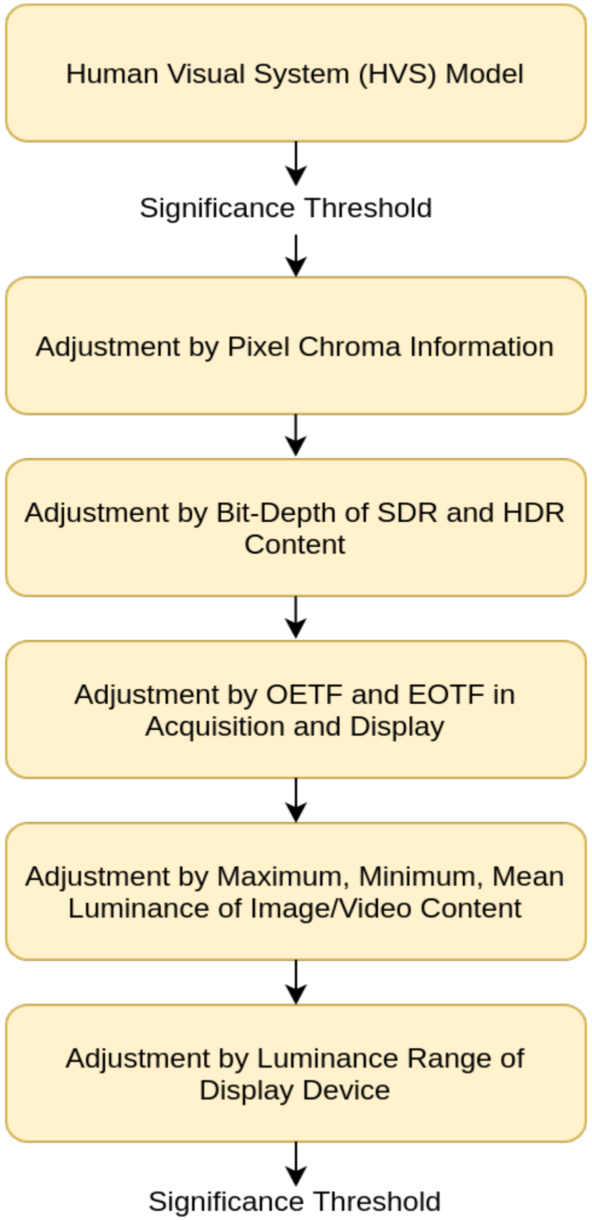
- Therefore, classifying pixels into significant and non-significant categories is the first step in detecting banding impairment. To classify pixels, a significant threshold is determined based on the characteristics of HVS as well as a series of signal and system properties.



- Determining the significance threshold is the key to detecting banding impairment. It requires a deep understanding of the HVS properties such as the contrast sensitivity function (CSF) and various visual masking effects.

Knowledge-driven method to detect banding

- The figure shows how the significance threshold is generated, starting with HVS modelling, and followed by adjustments based on important video workflow and display factors.
- Modelling CSF and visual masking of the HVS provides a starting point in determining the significance threshold, which would need to be tuned further to determine precisely the visibility of banding
- Banding is a local activity in smooth image regions that is visible under certain conditions and viewing environments. Therefore, not only signal properties, but also display devices and viewing conditions affect perceived banding



Knowledge-driven method to detect banding

- When all these content, perceptual, chroma, bit-depth, transfer function, and display factors are properly modelled, a precise prediction of visual banding may be achieved.

- The advantages of such knowledge-driven approaches is not only the high pixel-precision accuracy (that allows for the creation of banding maps) and low computational complexity, but also the high explainability – meaning that when banding happens, a deep investigation is plausible to find the cause of banding and then localize the problem to be fixed.

- The disadvantage of this approach is mainly in the difficulty of the modelling process itself, as precise models of the contributing factors are difficult to develop and parameters of such models are hard to calibrate.

Data-driven method to detect banding

- Machine learning approaches are generally data-driven, with black box models being trained by data samples.

- When these data samples are sufficiently representative of the real world data distribution, the trained model may be strong enough to make good predictions on novel data samples unseen in the training dataset

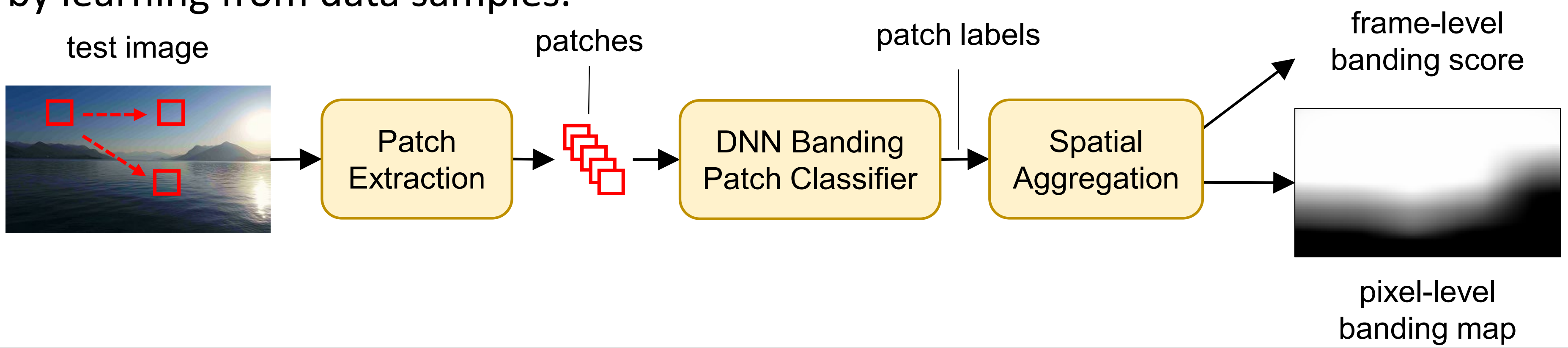
- The data-driven approach becomes a desirable option in the case of visual banding detection because it avoids the difficulty in developing and calibrating knowledge-driven models.

Data-driven method to detect banding

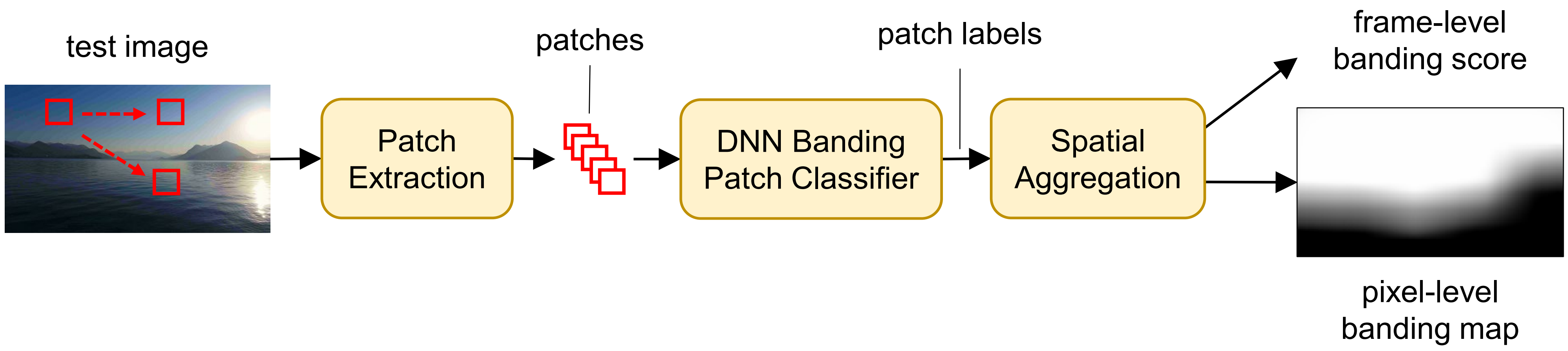
- The first step in building a deep learning based method is to obtain "big data", i.e., to construct a large-scale dataset for training, validation and testing

- This allows us to train a deep neural network (DNN), more precisely a convolutional neural network (CNN), to classify a given image patch as either with or without banding in an end-to-end manner

- Such a method is end-to-end because the DNN takes a raw image patch of pixels as input and directly produces a classification result as output. As such, the feature extraction process and the classifier are trained or optimized all together (as opposed to being constructed separately in traditional image classification methods) by learning from data samples.



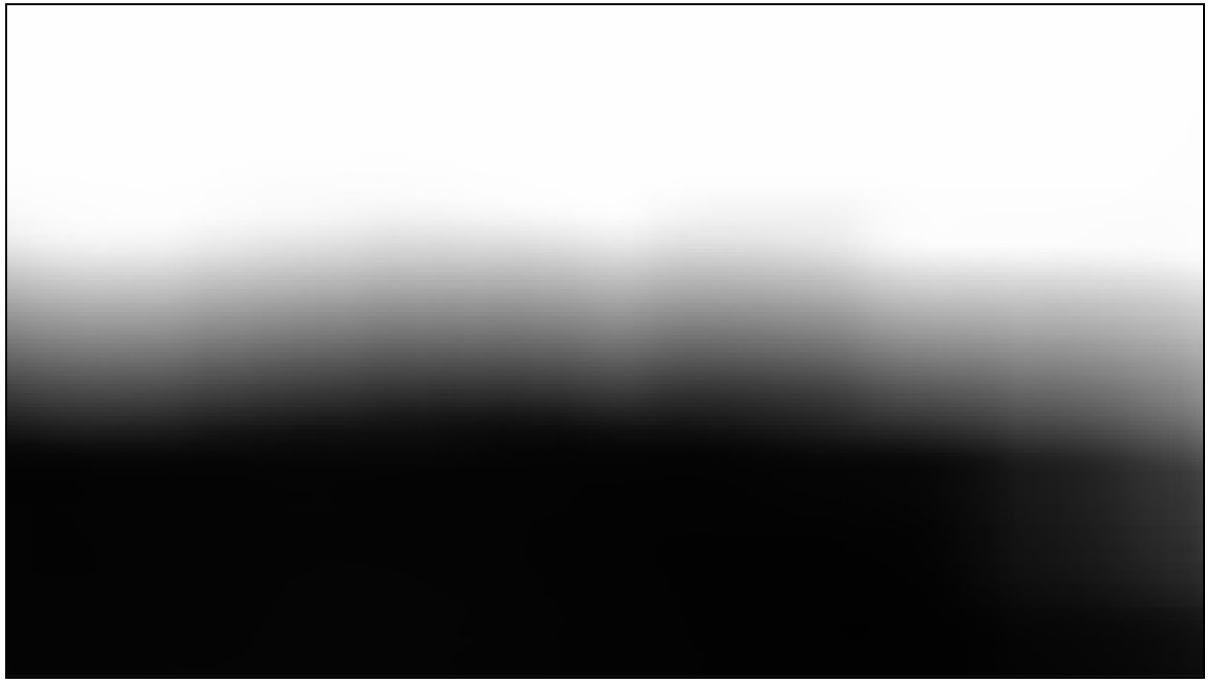
Data-driven method to detect banding



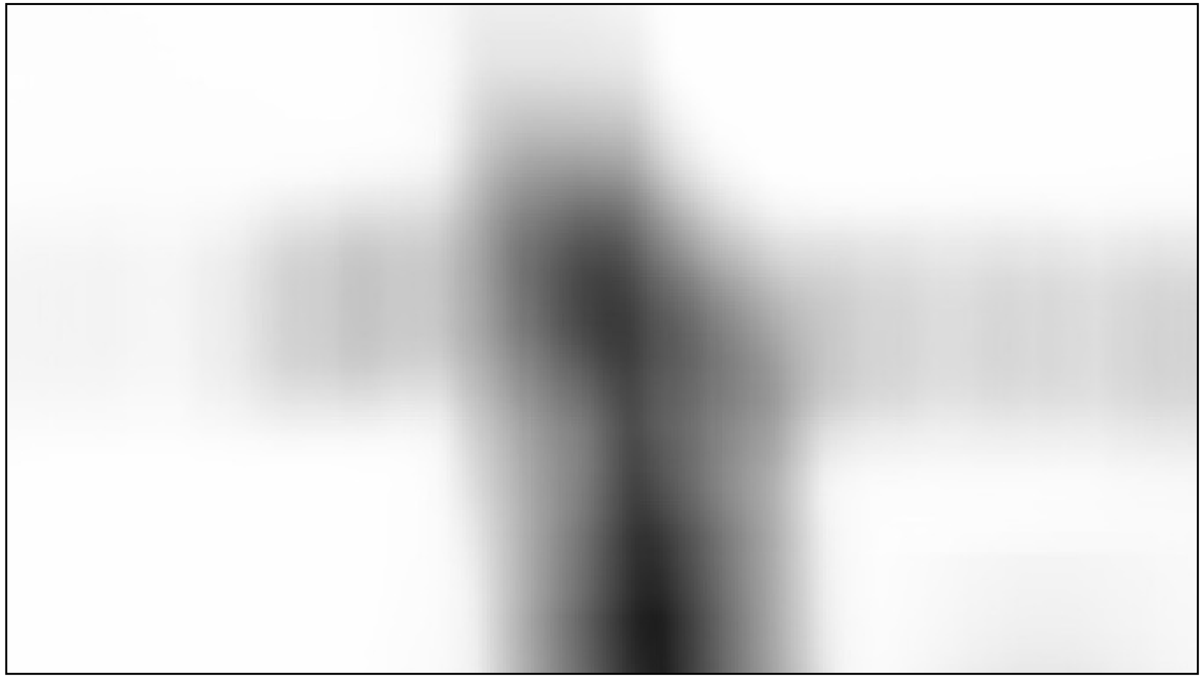
- When we have sufficient data samples for training, the CNN will converge to a stage that may make accurate classification results.

- The classification results obtained for individual local image patches through the CNN classifier are laid out spatially. They are then aggregated with pre-defined smoothness constraints into two outcomes. The first is a scalar frame-level banding score for the whole test image, and the second is a pixel-level banding map

Data-driven method to detect banding



Data-driven method to detect banding



Challenges

- First, there is no definite way to differentiate the real contours in the video content and the false contours of banding.

- Second, the full lifecycle of digital videos, from acquisition, production, distribution, to display, contains many operations that interact with the visibility of banding, and technologies behind these operations are evolving over time. These include but are not limited to OETF and EOTF transfer functions, colour space conversion and colour gamut mapping, colour subsampling and upsampling, dynamic range tone mapping, video encoding/decoding, and video pre-processing/post-processing.

- Third, the above are entangled with the never-ending progress of camera and display technologies, and the recent development of scene-adaptive and device-adaptive HDR/WCG processing in the new HDR standards such as HDR10+ and Dolby Vision. Consequently, banding detection will remain an open problem in the future and will evolve with the technology front of the digital video industry.

Conclusion

- We focused on the banding effect, an annoying visual artifact that appears in all stages of the life cycle of digital videos, and that has been drawing an increasing amount of attention with the recent growing popularity of UHD/HDR/WCG video content.

- We discuss the technical details of two promising but substantially different types of approaches for banding detection
  - ✓ Knowledge-driven approaches that are built upon deep understandings of the HVS and each component in the video acquisition, production, distribution and display workflows
  - ✓ Data-driven approaches that learn to detect banding by training DNN models with big data of labelled image samples.

- Despite the exciting progress made in the past decades on banding detection, there are still significant challenges and gaps in practice.