Video Quality Assessment

Learning Progress Report

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Learning Goals and Topics

- Explore how visual quality metrics quantify distortion and compression
- Understand DCT, SSIM, MS-SSIM, VMAF and their mathematical basis
- Analyze motion coherency and temporal NSS models for temporal consistency
- Simulate video sequences from static images and extract statistical features

PSNR & SSIM Fundamentals

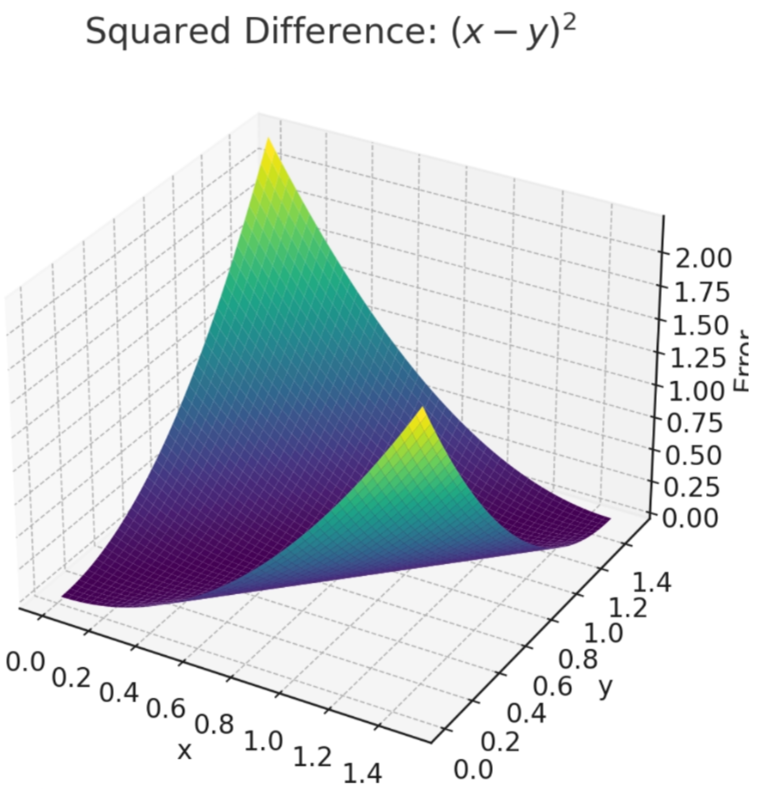
- **PSNR**: Measures pixel-level error using peak signal-to-noise ratio
  $PSNR = 10 \cdot \log_{10}\left(\frac{MAX^2}{MSE}\right)$

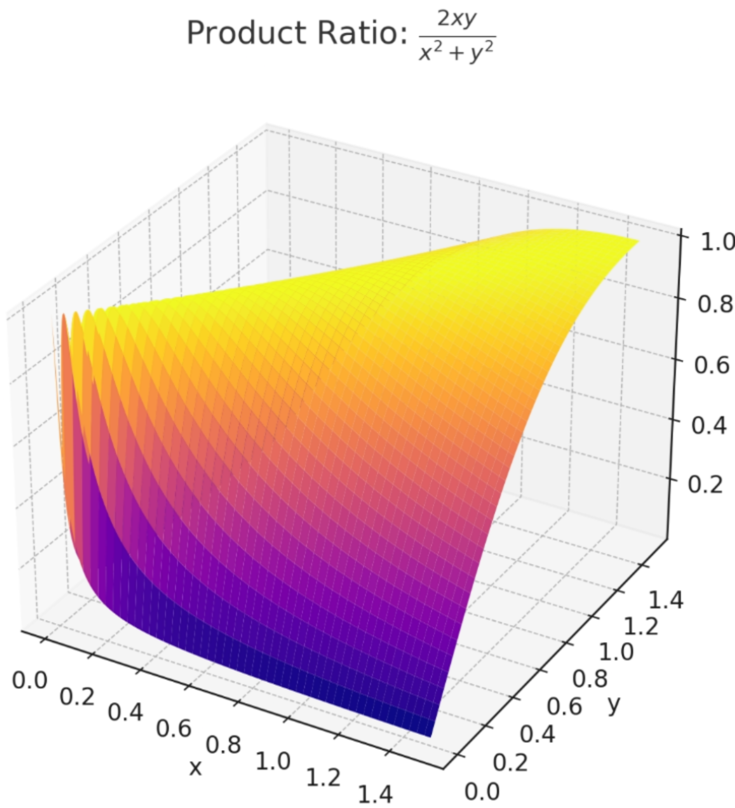
- **SSIM**: Structural Similarity Index considering luminance, contrast, structure
  $SSIM(x,y) = l(x,y) \cdot c(x,y) \cdot s(x,y)$

- My Question:
  - Compared additive vs multiplicative combinations for smoothness (e.g. Why use MSE in PSNR but use $l(x,y) = \frac{2\mu_x\mu_y + C_1}{\mu_x^2 + \mu_y^2 + C_1}$ in SSIM?)

- My guess
  - If both images are scaled by the same factor (e.g., made uniformly brighter), it won't significantly affect their similarity
  - Compared to simply using the absolute difference $|\mu_x - \mu_y|$, using a ratio-based method is more tolerant of slight brightness differences

PSNR & SSIM Fundamentals (Continued)





MS-SSIM and Gaussian Blurring

- **Multi-Scale SSIM**: Extends SSIM across different spatial scales
- Downsampling is applied via Gaussian blur → image pyramid
- Only the last level uses luminance comparison; others use contrast and structure
- My Question
  - Why use Gaussian blur instead of other downscaling or noise methods?
- My Guess
  - A low-pass filter should be applied before each downsampling step
    - Otherwise, high-frequency signals can alias into lower frequencies, resulting in unnatural artifacts or texture distortions

MS-SSIM and Gaussian Blurring (Continued)

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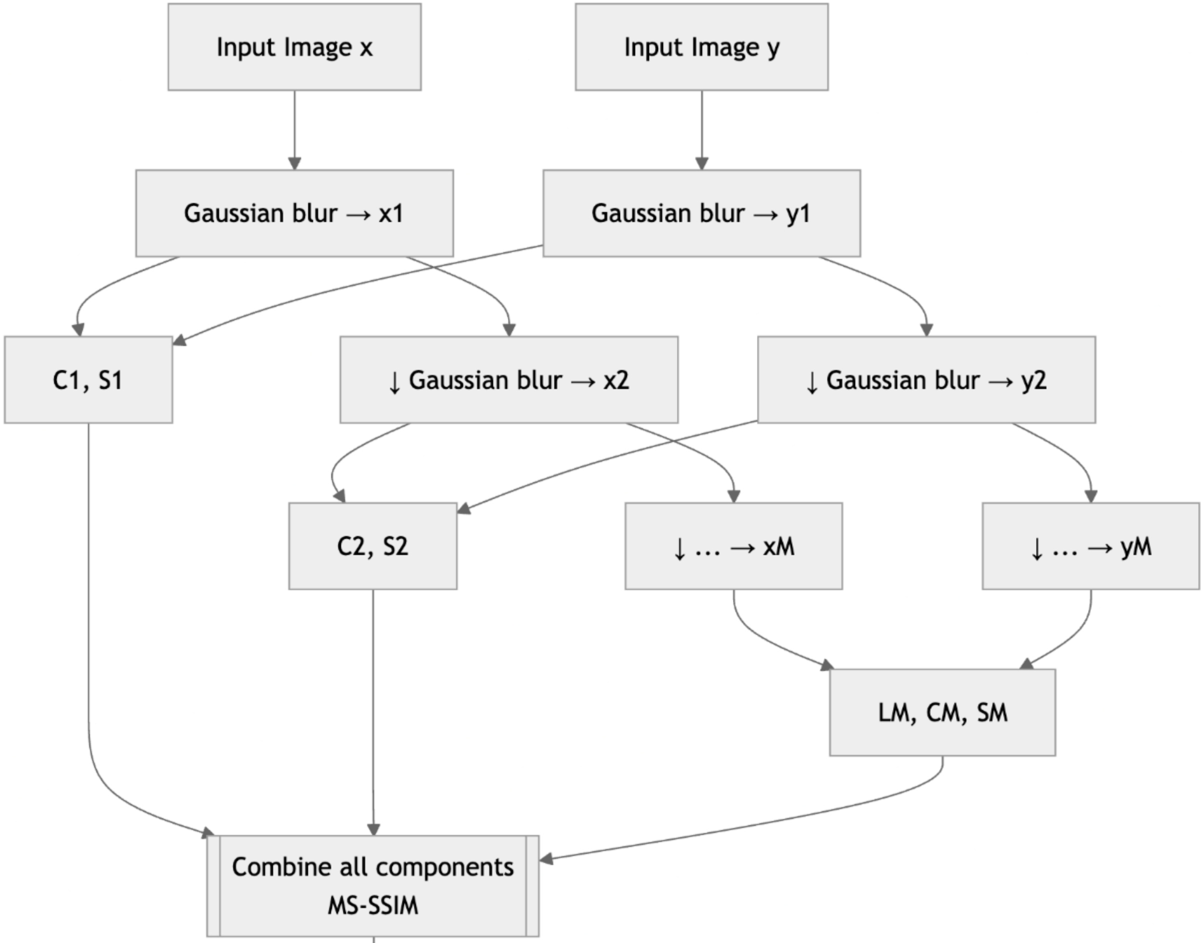


Gabor Filter & V1 Visual Cortex Modeling

- Gabor filter formula

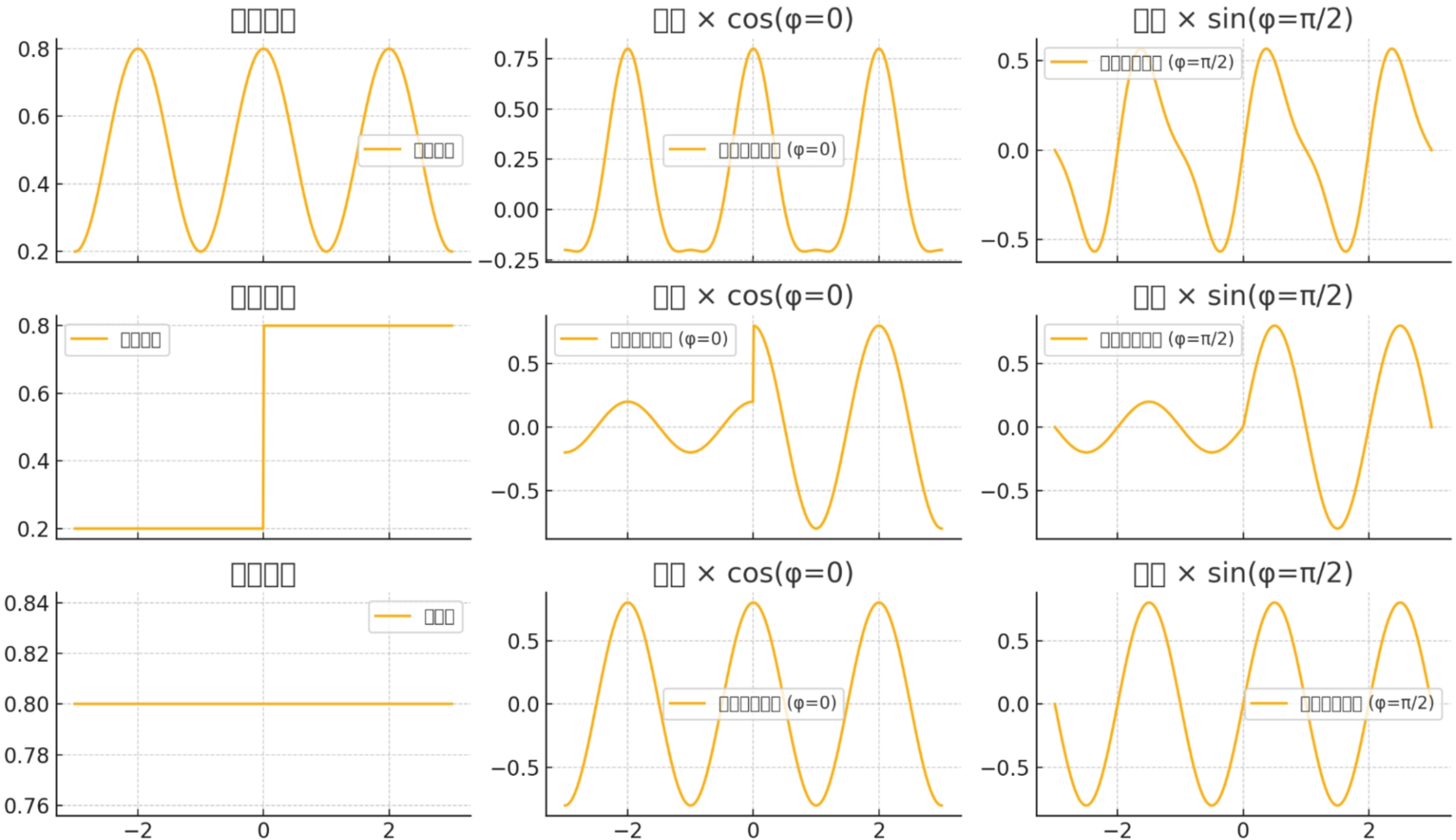
$$g(x, y) = \exp\left(-\frac{x'^2 + \gamma^2 y'^2}{2\sigma^2}\right) \cdot \cos\left(2\pi \frac{x'}{\lambda} + \phi\right)$$

- γ: ellipticity, simulates orientation bias in V1 neurons
- ϕ: even-symmetric vs odd-symmetric → sensitive to stripes vs edges
- Applied Gabor filtering to images to analyze local orientation patterns

Gabor Filter & V1 Visual Cortex Modeling (Continued)

- First Row: Stripe Input (e.g., regular wall textures)
  - $\varphi = 0$ (cosine, even symmetry): The stripes align with the filter's pattern ⇒ strong response, clear oscillation
  - $\varphi = \pi/2$ (sine, odd symmetry): The stripes align with the filter's zero crossings ⇒ signal cancels out on both sides, resulting in a very weak response
- Second Row: Edge Input (brightness transition)
  - $\varphi = 0$ (even symmetry): The edge falls in regions of opposite sign in the filter ⇒ moderate response due to partial cancellation
  - $\varphi = \pi/2$ (odd symmetry): The edge aligns with the filter's zero crossing ⇒ positive/negative regions align with bright/dark areas ⇒ strongest response
- Third Row: Bright Region Input (uniform brightness area)
  - Both filters produce little to no response

Gabor Filter & V1 Visual Cortex Modeling (Continued)



Blind Image Integrity Notator using DCT Statistics（BLIINDS)

- **DCT**: Discrete Cosine Transform is used to convert a signal from the spatial domain (e.g., an image) to the frequency domain

  $\cos\left[\frac{\pi}{N}(x+0.5)u\right]$: projects onto orthogonal cosine basis
- **GGD**: Generalized Gaussian Distribution

  $$f(x;\alpha,\beta)=\frac{\beta}{2\alpha\Gamma(1/\beta)}\cdot\exp\left(-\left(\frac{|x|}{\alpha}\right)^{\beta}\right)$$

Parameter	Value Range	Distribution Shape	Interpretation (Applied to Images)
$\beta=2$	Gaussian	Smooth in flat regions, weaker edges	Indicates natural texture with no strong compression or noise
$\beta<1$	Heavy-tailed	Sharper peaks, more noise or abrupt changes	Suggests presence of compression artifacts or strong edges
α	Any positive value	Controls overall spread	Can reflect image contrast or texture richness

- My Question:

Blind Image Integrity Notator using DCT Statistics（BLIINDS)

- My Question:
  - Why using GGD for the model, not GMM (Gaussian Mixture Model), GSM (Gaussian Scale Mixture)?

Thank You