IMAGE QUALITY ASSESSMENT BASED ON DCT SUBBAND SIMILARITY

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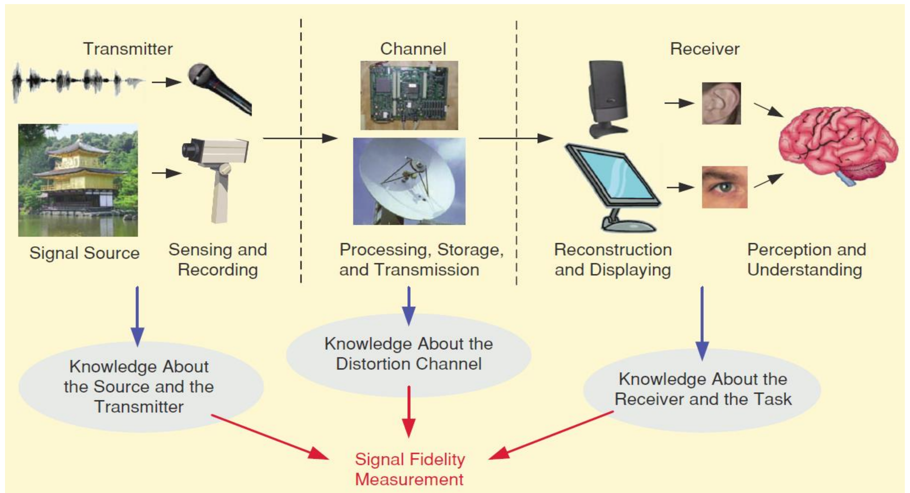
1. Image Quality Assessment

- Image Quality Assessment (IQA) becomes increasingly important
  - Benchmark image processing systems and algorithms
  - Monitor quality control systems
  - Optimize image processing algorithms parameter values
- A challenging task
  - Requires modeling of a complex transmitter-channel-receiver path



(Wang & Bovik, 2009)

Problem Formulation

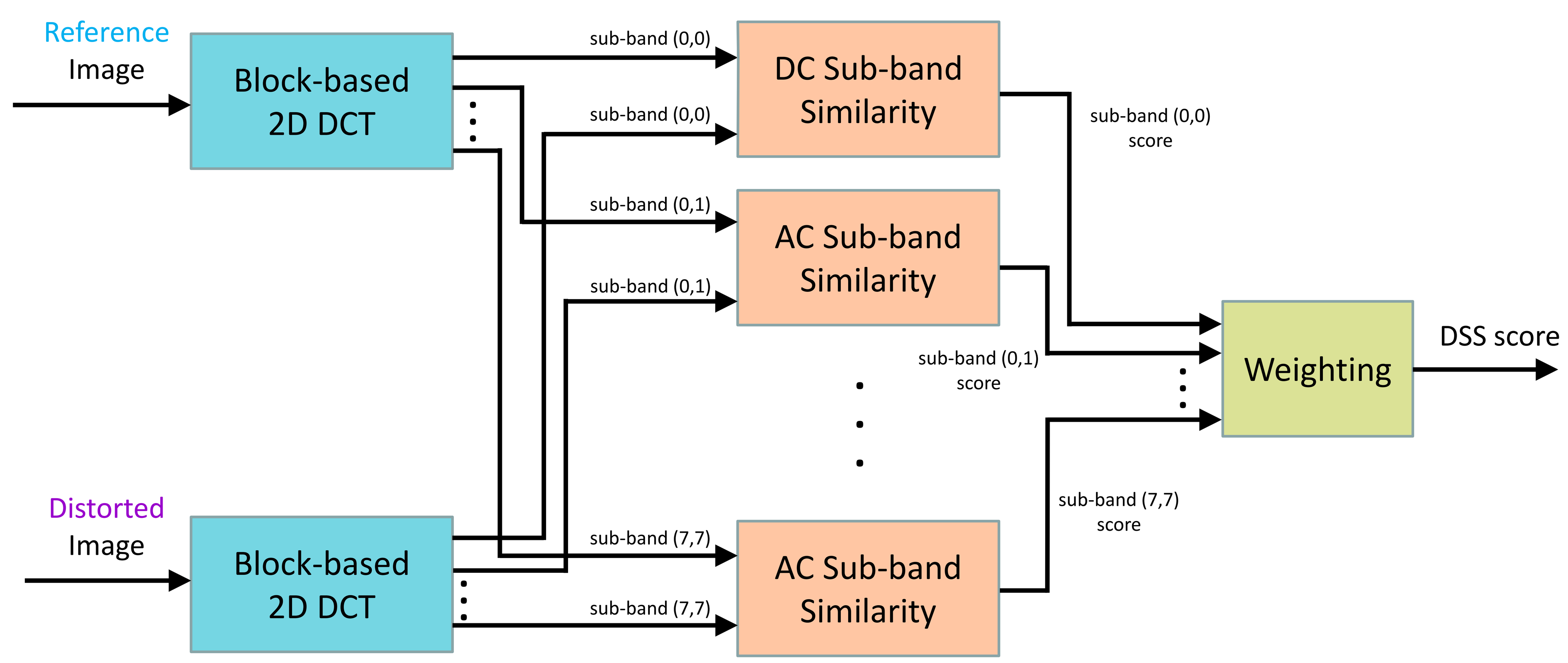
- **Objective** quality assessment is performed using mathematical models that predict results of subjective human assessment
- Three approaches for IQA:
  - **Full Reference** – Compare original to distorted image
  - No Reference – Assess quality using only distorted image
  - Reduced Reference – Extract features from both original and distorted image and compare them

Full Reference Methods

- **PSNR** – Peak Signal to Noise Ratio, related to MSE
- **VSNR** (Chandler & Hemami, 2007), **MAD** (Seshadrinathan & Bovik, 2009) – Threshold distortions based on HVS properties
- **SSIM** (Wang et al., 2004) – Structural Similarity, measures distortion of 3 elements: luminance, contrast and structure
- **MS-SSIM** (Wang et al., 2004), **FSIM** (Zhang et al., 2011) - Also account for structure, improve SSIM by exploiting additional HVS properties
- **VIF** (Bovik et al., 2006) - Quantify the amount of information that can ideally be extracted from an image

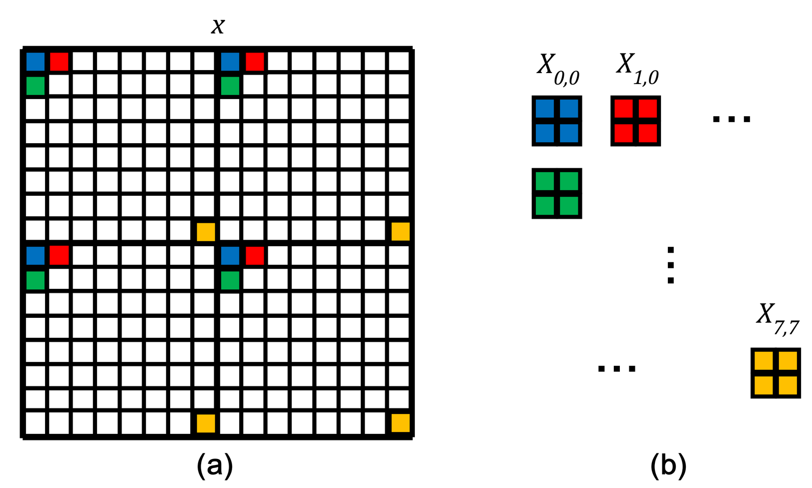
2. Proposed Image Quality Assessment Technique - DCT Sub-band Similarity (DSS)

- Measure image quality by accounting for variances in the DCT domain
  - Allows weighting of spatial frequencies according to HVS (Human Visual System) sensitivity
  - Fits naturally the scheme of modern image and video coders
  - The distributions of DCT coefficients of distorted and nondistorted images has different variance (Lam & Goodman, 2000), (Saad & Bovik, 2012)
- Three stages:
  - DCT **sub-band decomposition**
  - DCT **sub-bands similarity** evaluation
  - Sub-band scores **weighting** to a scalar quality score



2.1. DCT Sub-band Decomposition

- 2D 8x8 block-based DCT
- Spectral decomposition



(a) 8x8 2D DCT transform of a dummy image of size 16x16 and
(b) a decomposition of its coefficients into 64 sub-bands

2.2. DCT Sub-bands Similarity Evaluation

- Calculate **local** DCT **sub-band variances**
  - **Local** => HVS perceives local image regions
  - **Sub-band variances** => relate to auto-correlation (structure) in spatial domain
- Point-wise comparison between local variances of corresponding sub-bands:

$$DSS_{m,n}(p,q) = \frac{2\sigma^X_{m,n}(p,q)\sigma^Y_{m,n}(p,q) + C}{\sigma^X_{m,n}(p,q)^2 + \sigma^Y_{m,n}(p,q)^2 + C}$$

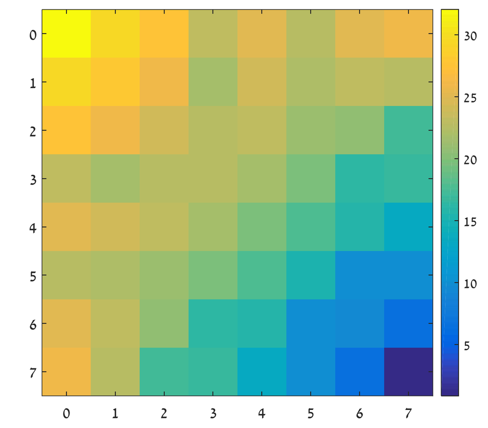
$\sigma^X_{m,n}(p,q)$ and $\sigma^Y_{m,n}(p,q)$ are the local variances of the subband (m,n) in the reference and distorted image respectively. C is a constant for numerical stability.

- Spatial pooling: $DSS_{m,n}(p,q) \rightarrow DSS_{m,n}$
  - HVS is sensitive to worst spatial distortions => Average only lowest scores

2.3. Weighting of Sub-bands Scores

- HVS has higher sensitivity to distortions in low spatial frequencies
- Use a Gaussian weighting function

$$DSS = \sum_{m,n=0}^{7} w_{m,n} DSS_{m,n}$$



$\log(w_{m,n})$ where $w_{m,n}$ is the weight of the subband (m,n)

3. Results

		PSNR	SSIM	MSSIM	VSNR	VIF	MAD	FSIM	DSS
SROC	LIVE	0.876	0.910	0.944	0.928	0.963	0.968	0.963	**0.970**
	CSIQ	0.806	0.837	0.914	0.811	0.919	0.947	0.924	**0.953**
	TID	0.525	0.645	0.853	0.705	0.750	0.834	0.881	**0.891**
	Avr.	0.736	0.797	0.904	0.815	0.877	0.916	0.923	**0.938**
LCC	LIVE	0.870	0.938	0.933	0.923	0.960	**0.968**	0.960	**0.968**
	CSIQ	0.800	0.815	0.897	0.800	0.925	**0.950**	0.912	**0.950**
	TID	0.536	0.652	0.839	0.682	0.806	0.831	0.874	**0.897**
	Avr.	0.735	0.802	0.890	0.802	0.897	0.916	0.915	**0.938**
RMSE	LIVE	13.368	11.790	8.946	10.506	7.673	6.900	7.678	**6.830**
	CSIQ	0.158	0.133	0.115	0.158	0.098	0.082	0.108	**0.078**
	TID	1.137	0.851	0.730	0.982	0.789	0.750	0.653	**0.593**
running time [ms]		**5**	95	270	60	2000	2800	1350	200

Performance of DSS and other image quality assessment techniques on images from the LIVE, CSIQ, and TID databases. Performance is measured in the Spearman rank-order correlation coefficient (SROC), the Pearson linear correlation coefficient (LCC) and the Root Mean Square Error (RMSE), between the subjective scores and the objective quality indices. The best results are in **bold**.

4. Conclusion

- High demand for Image Quality Assessment
- However, objective IQA is a difficult task
- The proposed DSS technique has many advantages
  - ✓ Results are **better than state-of-the-art**
  - ✓ Suitable for **real-time** performance
  - ✓ **Easy to implement**
  - ✓ Easy extension to a **reduced-reference** configuration and to **video** quality assessment (ongoing work)

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