Learning to Predict Localized Distortions in Rendered Images

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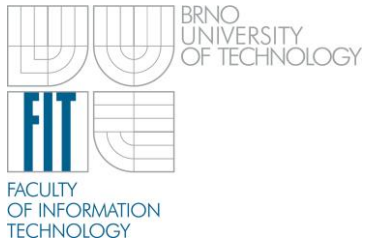
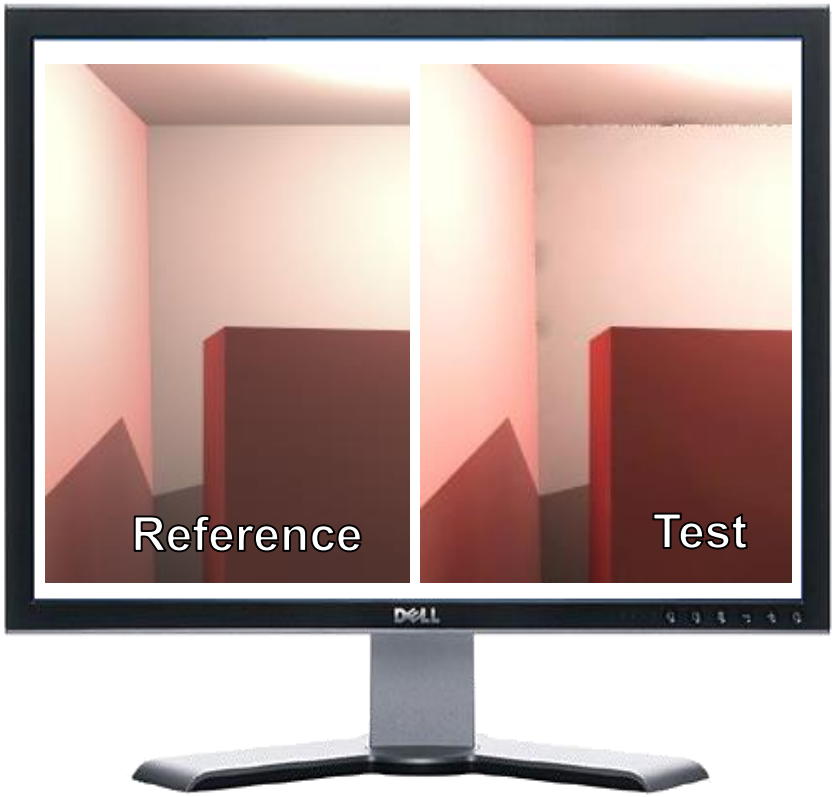


Outline

- Full-reference Image Quality Metrics (IQM)
- New feature descriptors for IQM
- Analysis of feature descriptors
- Visual saliency analysis (eye tracker data)
- New data-driven Image Quality Metric
- New synthetic dataset
- Optimization of parameters of existing metrics
- Conclusions and future work

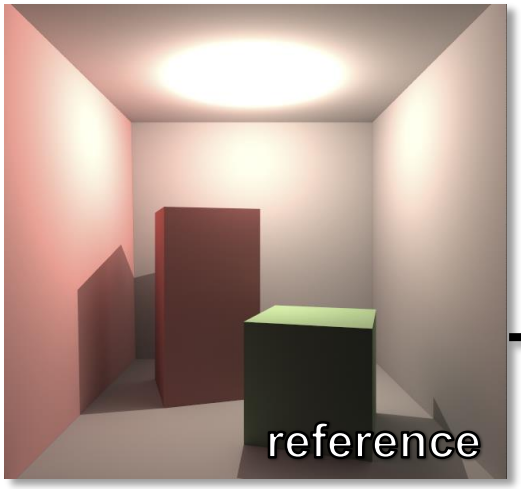
FR Image Quality Assessment

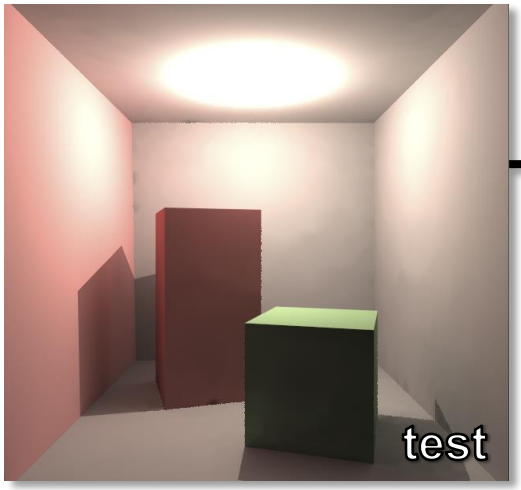


Rate the Quality/ Visibility of Artifacts

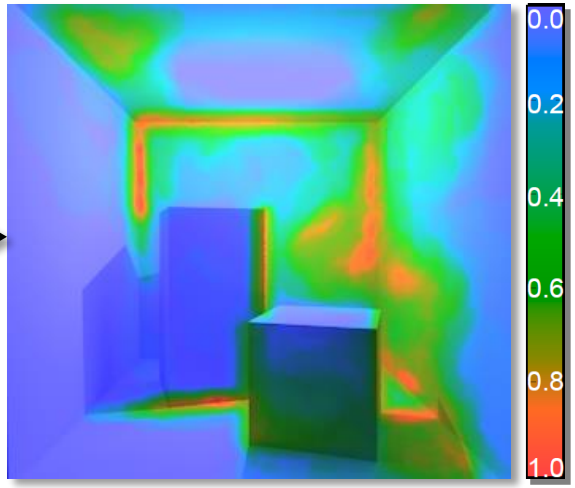
Subjective Experiments: + Reliable
– High Cost

Full-Reference Image Quality Metrics





FR
IQM

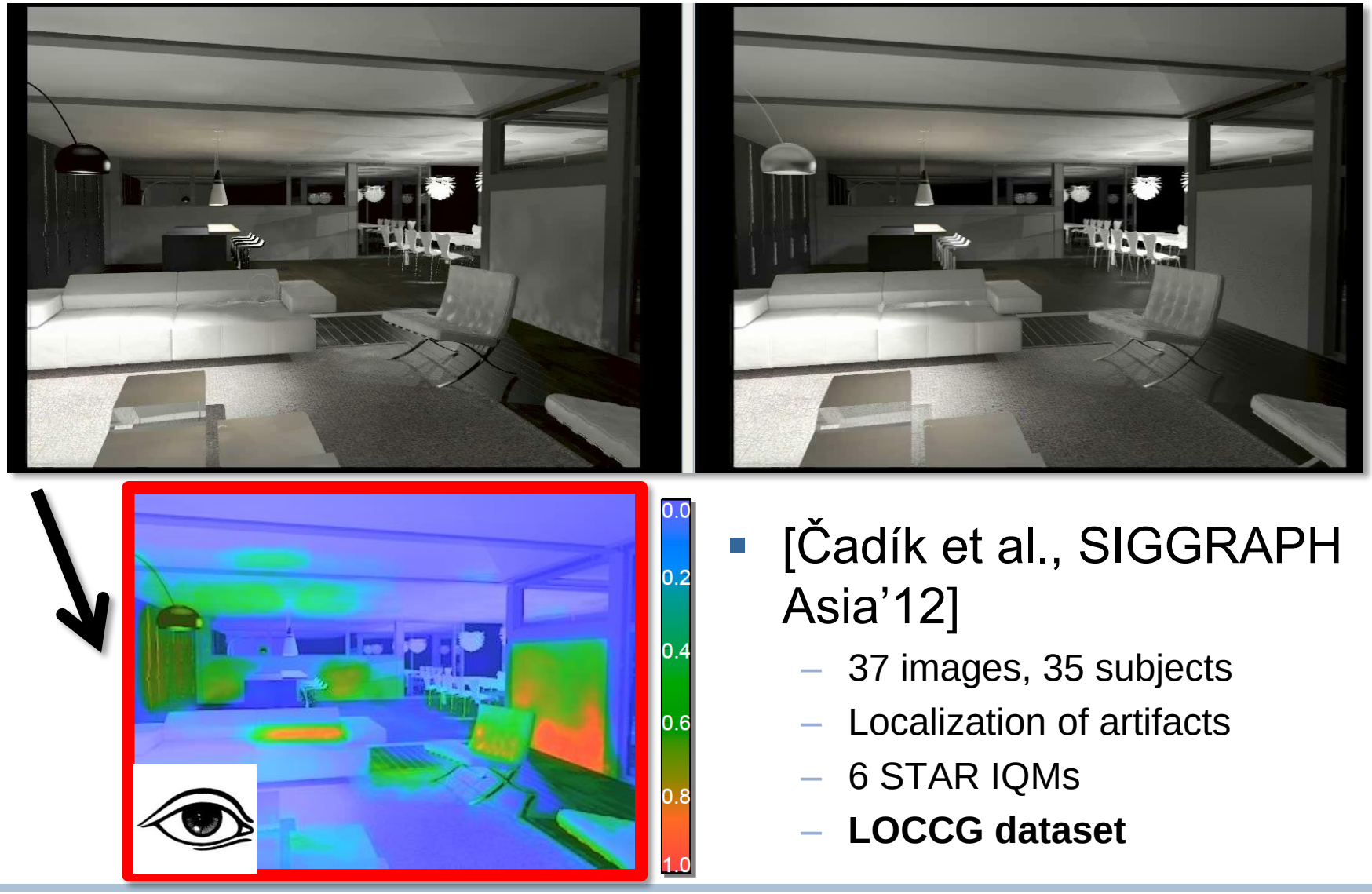


localized
distortion map

Full-Reference Metrics

- What are they good for besides that?
  - Quality assessment scenarios in compression/transmission, etc.
  - Algorithm analysis/validation/evaluation
  - Guiding/ parameter estimation of renderers
  - Stopping criterions
  - Speed/ quality enhancements
- Are they reliable?

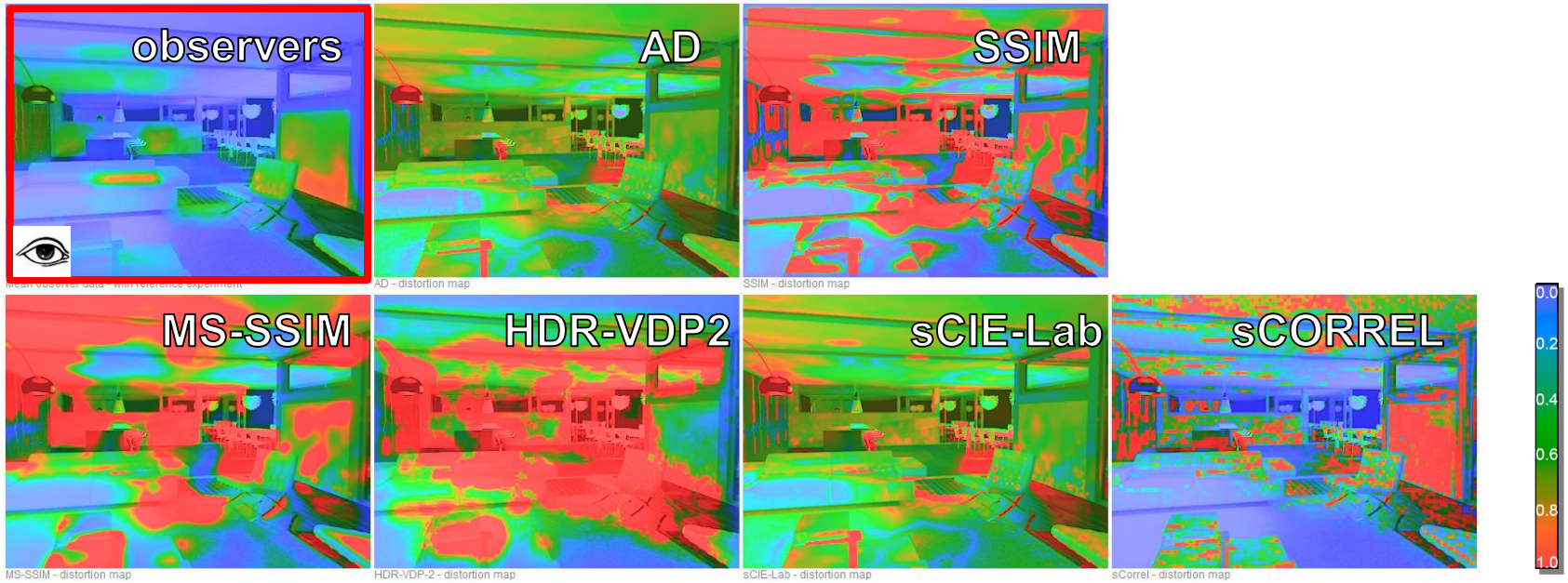
Evaluation of STAR FR-IQM



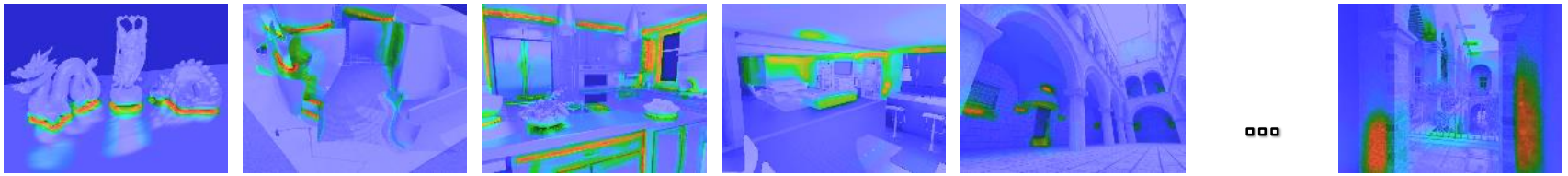
- [Čadík et al., SIGGRAPH Asia'12]
  - 37 images, 35 subjects
  - Localization of artifacts
  - 6 STAR IQMs
  - **LOCCG dataset**

Results of the Experiment

- State-of-the-art IQMs far from subjective ground-truths
- No universally reliable metric exists
- Large space for improvements…

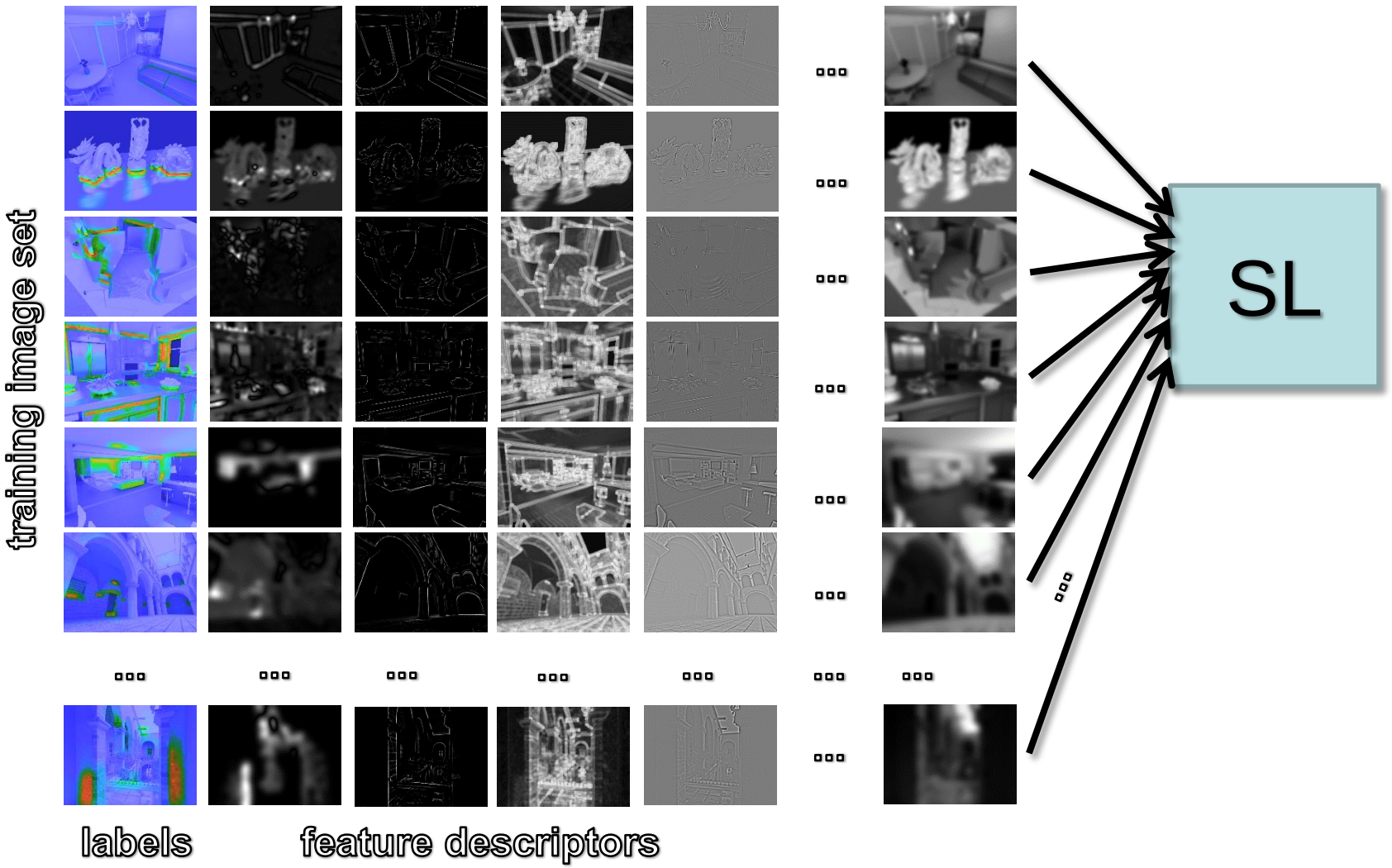


How to Improve Metrics Performance?

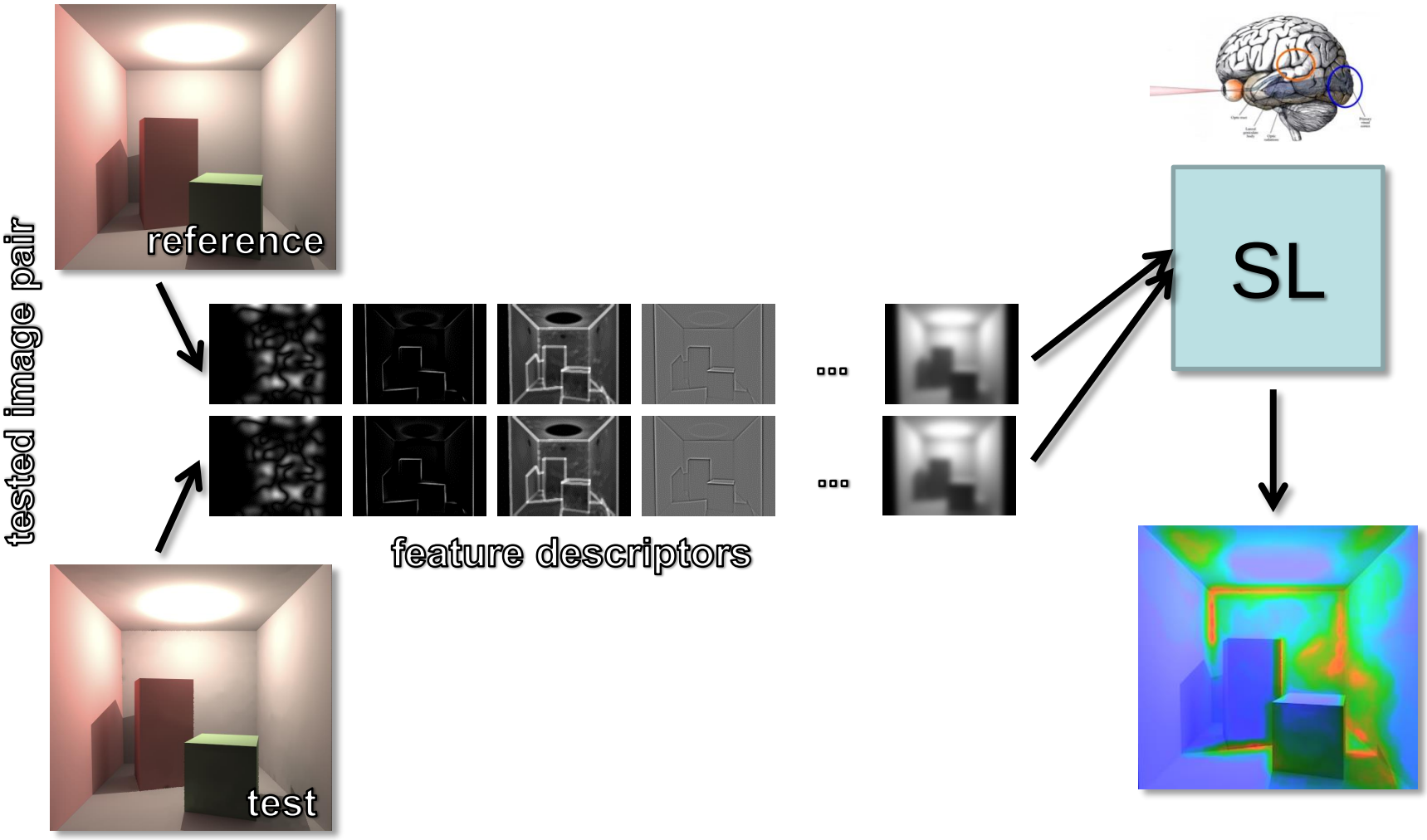


- Sufficient amount of subjective data → data-driven approach (machine learning)
- Supervised learning (e.g. SVM, decision forests)
  - Labels (distortion maps)
  - Feature descriptors

Supervised Learning – Training Phase



Supervised Learning – Prediction



New feature descriptors for IQM

- Computer vision
  - **BOW (bag-of-visual-words)**, HOG (histogram of oriented gradients), dense SIFT, Harris corners, phase congruency
- Statistics
  - Spearman correlation, gradient distance, entropy, **signed difference**, luminance, mean, variance, kurtosis, skewness
- Parts of previous metrics
  - SSIM (**SSIM_struct**, SSIM_con, SSIM_lum, HDR-VDP-2, sCIE-Lab, absolute difference)
  - Multiscale versions (low-pass & band-pass)
- High-level visual features
  - Variations of SSIM features, **masking entropy**
  - Contrast term with masking, contrast with inhibition
  - Artifact plausibility
  - Patch frequency, Location prior, etc.

Analysis of Features for IQM

- In total 32 feature vectors, 233 dimensions

1) How important is a feature?
2) What features give the best IQM performance?

- Feature selection
  - Greedy feature selection
  - Stacked classifiers
  - Decision forests
  - ROC analysis

Analysis of Features for IQM

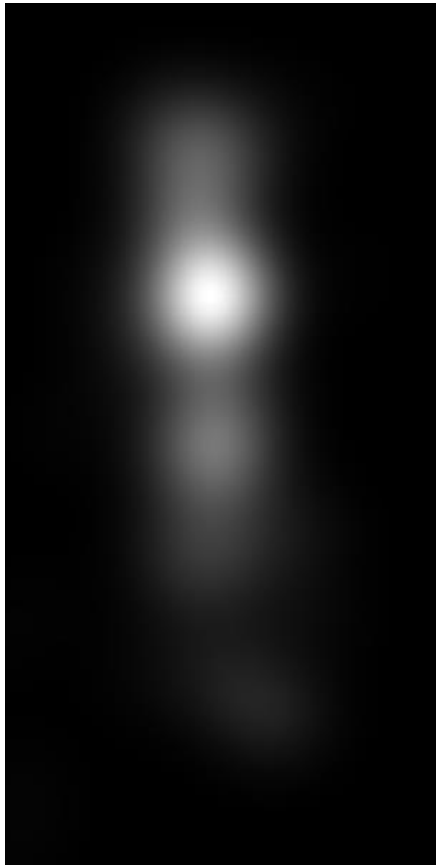
- Greedy feature selection (SVM)
  - Adds features with smallest cross-validation error
  - Combination of complete features
- Stacked classifiers (SVM)
  - Non-linear classifiers (per feature) + one linear classifier → weights
- Decision forests
  - Feature selection at each tree node
- ROC analysis
  - Identifies strong features, does not count with correlations and combination of features

	Feature Name	Dim.	Multi scale	Import. multi-dim. (greedy)	Import. multi-dim. (stacking)	Import. scalar (dec. trees)	Import. scalar (AUC)
1	ad [Sec.3.1]	11	✓				
2	bow [Sec.3.2]	32			1.0	1.0	
3	dense-sift diff [BZM07]	1		0.72047			0.86216
4	diff [Sec.3.3]	11	✓		0.48596	0.66906	
5	diff mask [Sec.3.3]	1		0.19609			0.85772
6	global stats [Sec.3.3]	5					
7	grad dist [Sec.3.3]	1					
8	grad dist 2 [Sec.3.3]	1			0.32785	0.66382	0.85919
9	Harris corners [HS88]	12	✓			0.76699	
10	hdrvdp band [MKRH11]	6	✓			0.68933	0.85035
11	hdrvdp band log	6	✓				
12	hog9 [DT05]	62			0.46443		
13	hog9 diff [Sec.3.2]	1			0.32178	0.67821	
14	hog4 diff [Sec.3.2]	1					
15	location prior [Sec.3.4]	2					
16	lum ref [Sec.3.3]	11	✓	0.58963			
17	lum test [Sec.3.3]	11	✓	0.21429			
18	mask entropy I [Sec.3.3]	1		0.40419	0.52820	0.99389	0.86358
19	mask entropy II [Sec.3.3]	5	✓	1.0		0.67035	0.86676
20	patch frequency [Sec.3.4]	1			0.41590		
21	phase congruency [Kov99]	10	✓	0.19712			
22	phow diff [BZM07]	1					
23	plausibility [Sec.3.4]	1			0.32051		
24	sCorrel [Sec.3.3]	1		0.18956			0.8496
25	spyr dist [Sec.3.3]	1				0.85793	
26	ssim con [WBSS04]	11	✓				0.8496
27	ssim con inhibit [Sec.3.1]	1			0.44840		0.84517
28	ssim con bal [Sec.3.1]	1					
29	ssim con bal max [Sec.3.1]	1					
30	ssim lum [WBSS04]	11	✓	0.58791			
31	ssim struc [WBSS04]	11	✓	0.18681	0.53080	0.65608	0.86484
32	vis attention [Sec.3.5]	1					
Metric performance (AUC)				0.880	0.897	0.916	0.892

Visual Saliency Analysis

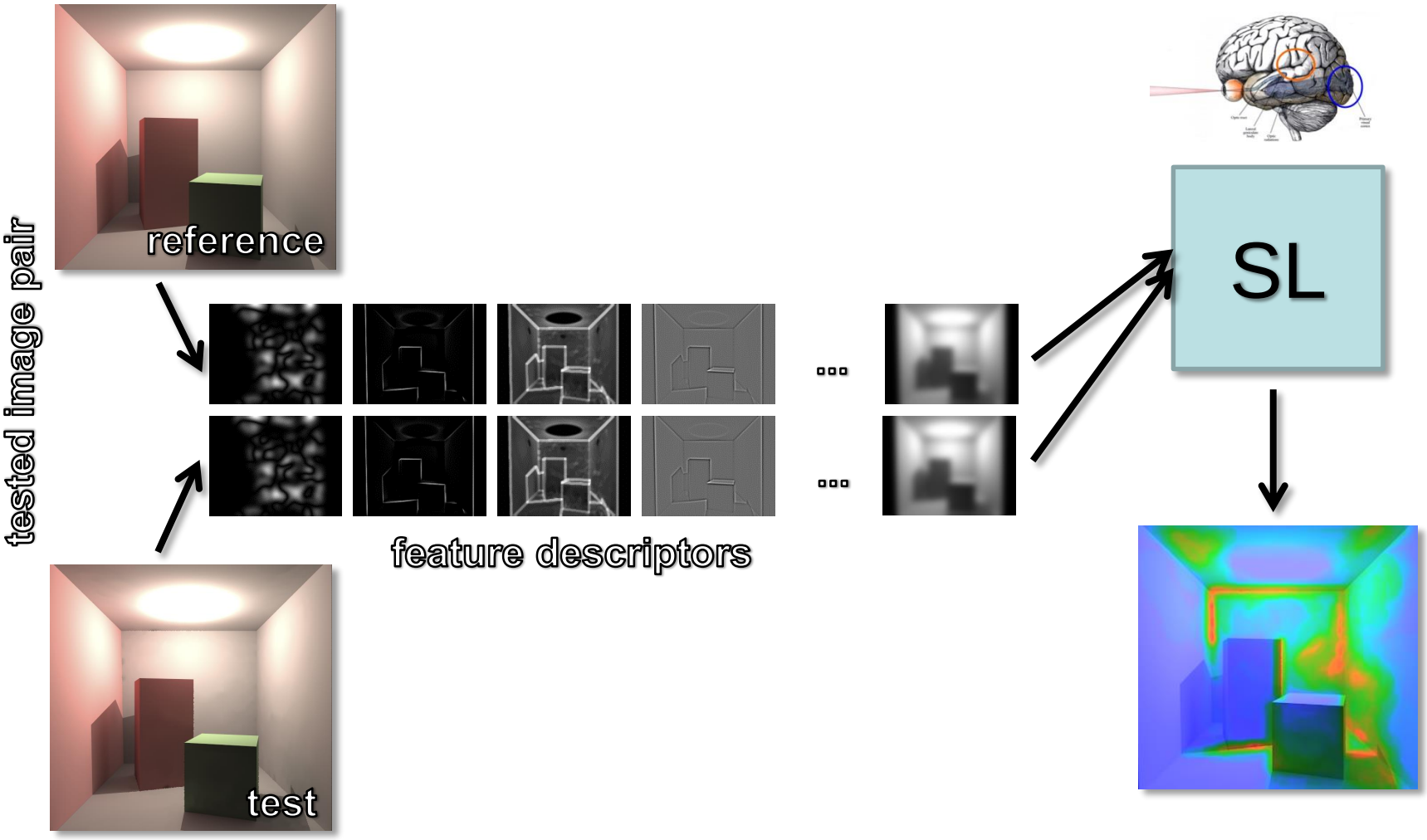
- Does knowledge of visual attention improve IQM?
- Acquired by eye-tracker (SMI P-CR RED250)
  - Observation: 12s per image
  - Averaged over 13 subjects
- Analyzed in the framework as normal feature
  - Measured saliency **does not improve predictions**
- Data publicly available for download for future research

visual stimulus



measured saliency

New Data-driven Image Quality Metric



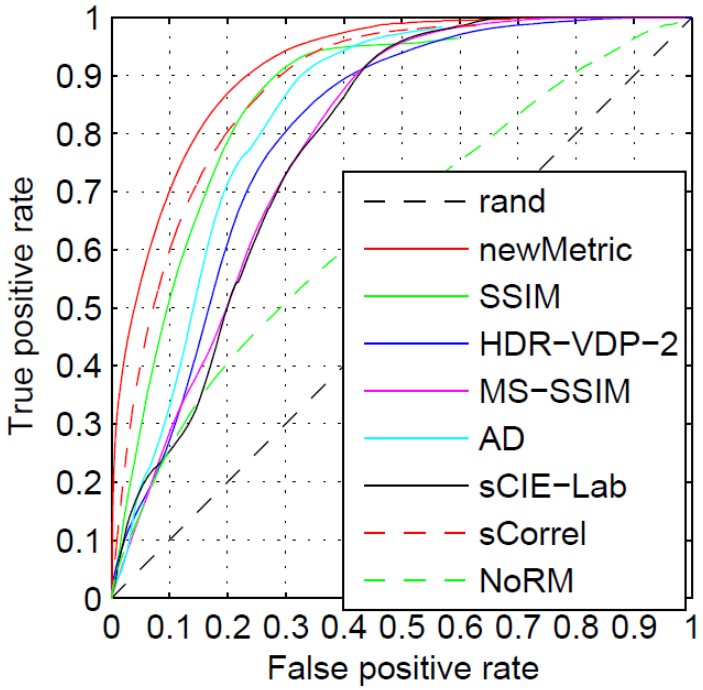
New Data-driven Image Quality Metric

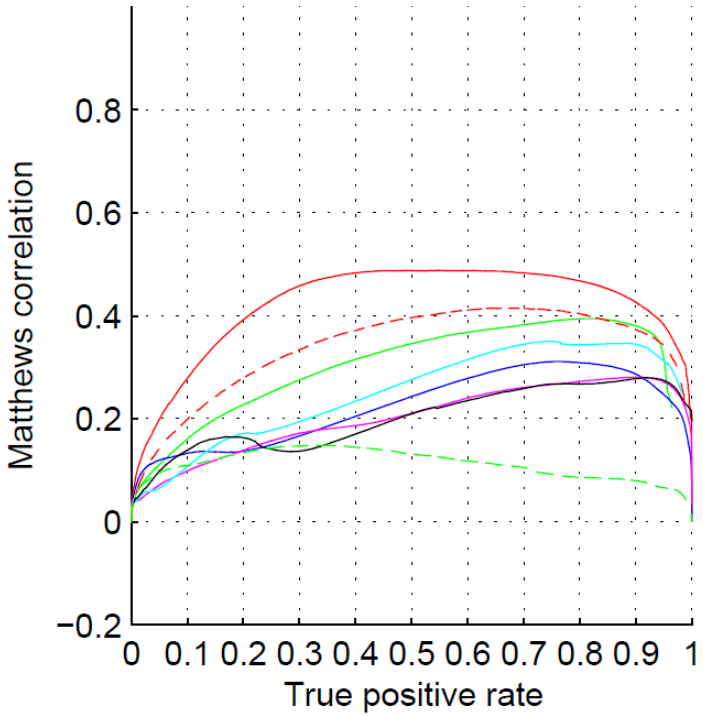
- SL=ensembles of bagged decision trees
  - t=20 trees, avg. depth=10
- 10 best features ranked by feature selection
- LOCCG dataset for training

- Advantages
  - Computer graphics content
  - Many distortion types
  - Superposition of distortions

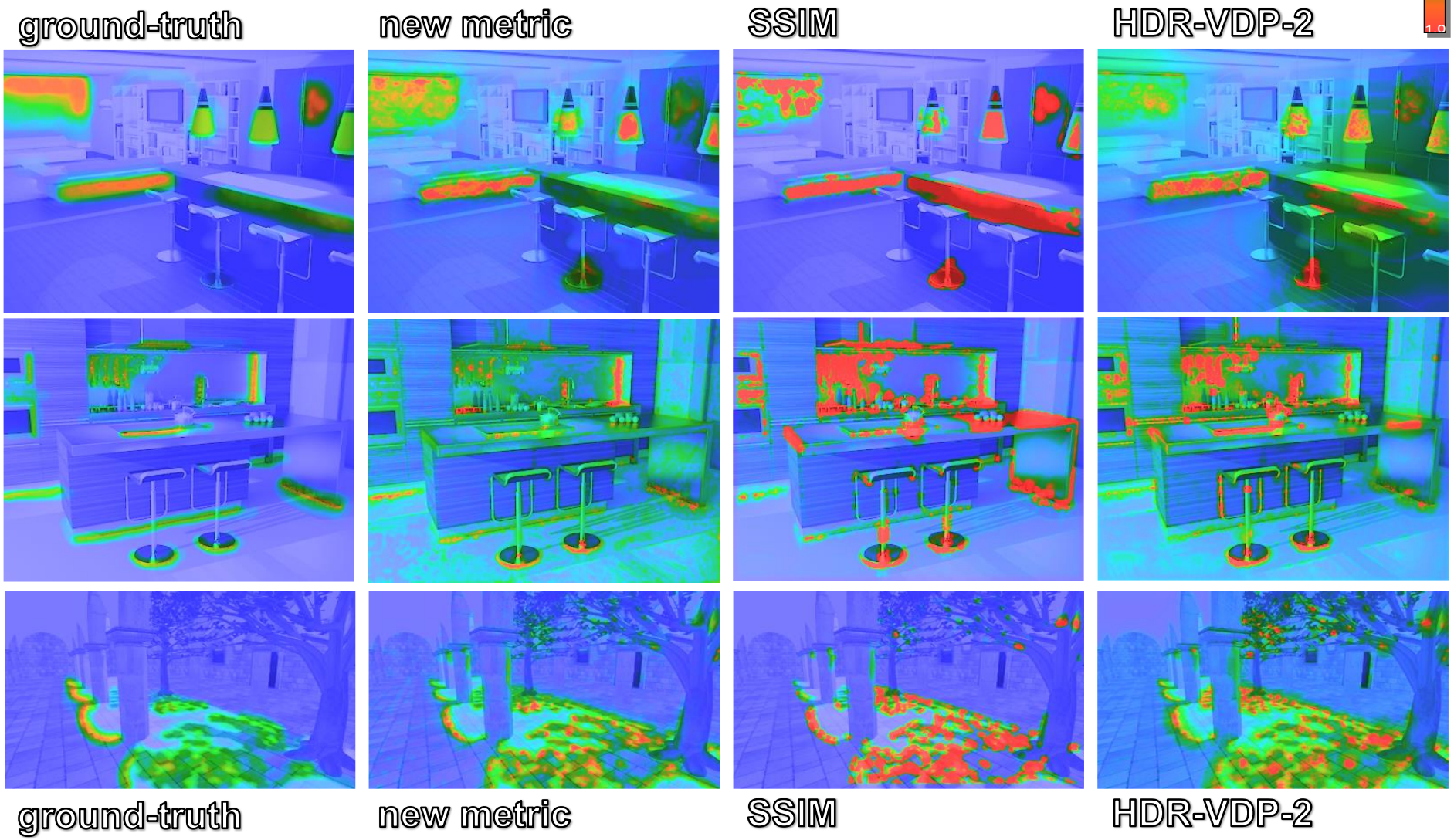
New Image Quality Metric – Performance

- Metric performance – ROC analysis
  - LOCCG dataset – leave one out cross validation
  - Compared to 7 state-of-the-art IQM



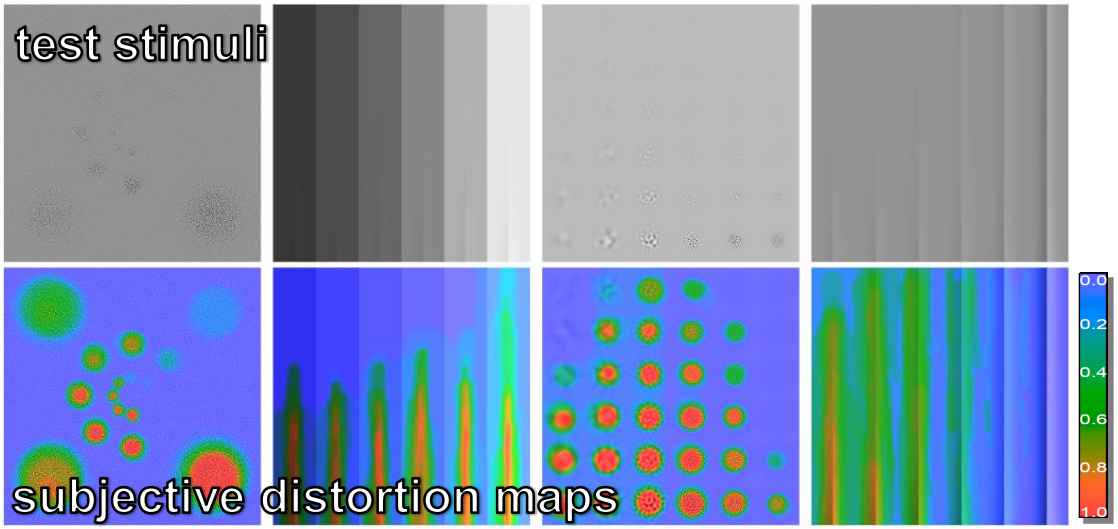


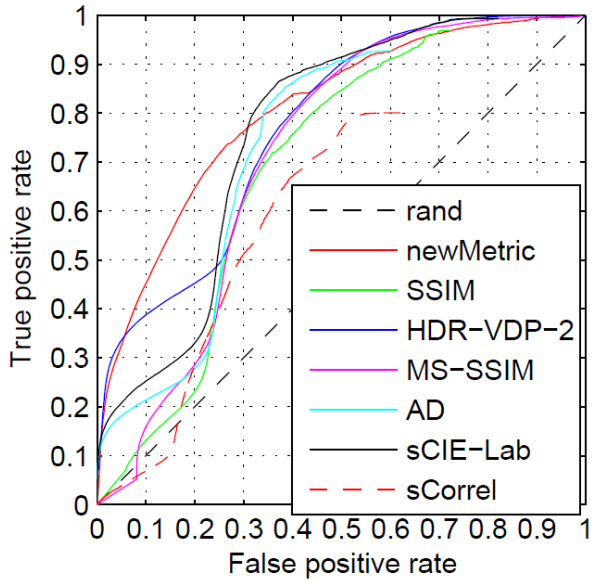
New Image Quality Metric – Results



New Synthetic Dataset

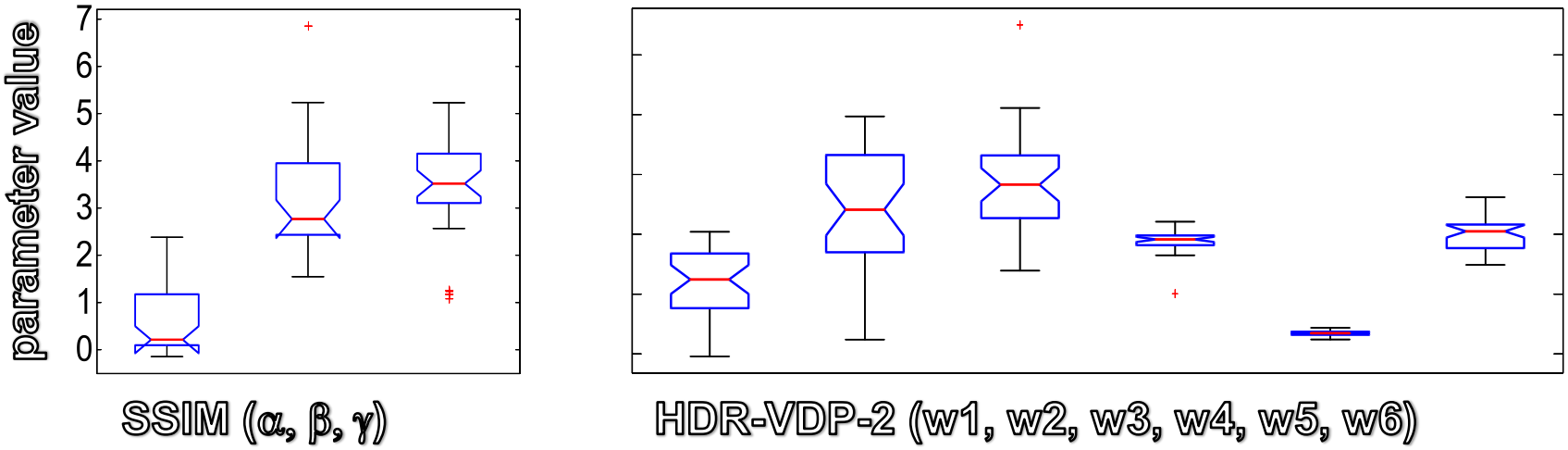
- Contrast-Luminance-Frequency-Masking (CLFM)
- 14 stimuli (image pairs), 13 subjects
- Learning “real-world” (LOCCG) → good results on synthetic data (CLFM) (**not** vice-versa)
- Available for download at project webpage



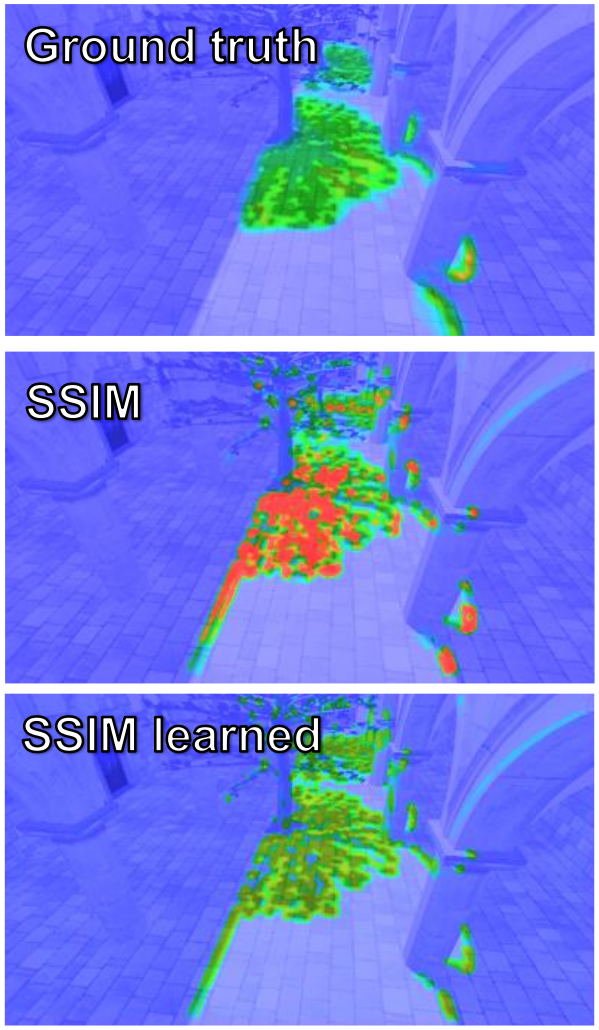


Optimizing Parameters of Existing IQMs

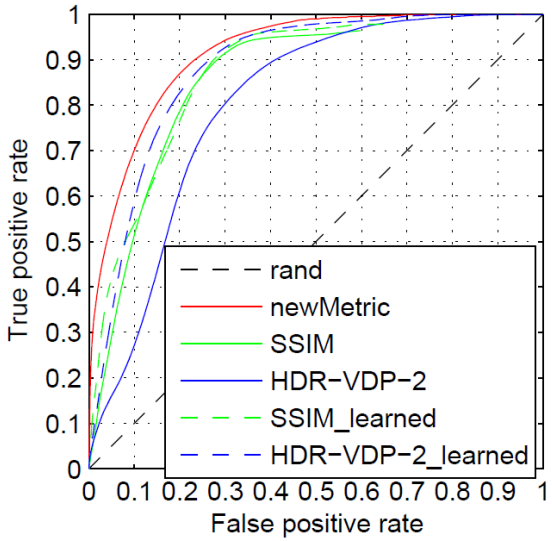
- IQM features → stack of classifiers → weights = optimized parameter values
- HDR-VDP-2 [Mantiuk et al., SIGGRAPH'11]
- SSIM [Wang and Bovik, '06]

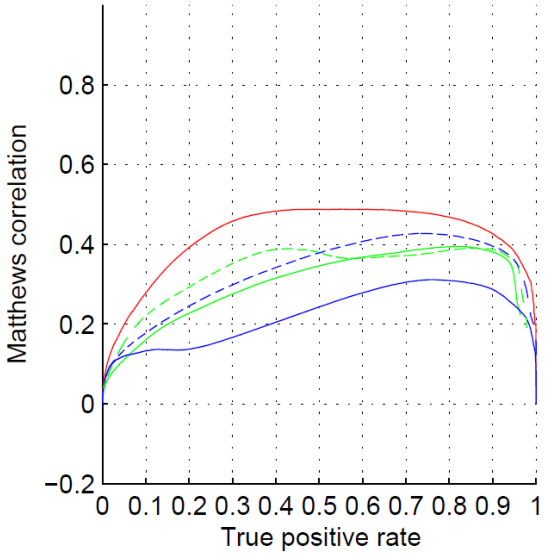


Optimizing Parameters of Existing IQMs



- Improved performance for rendering artifacts





Conclusions

- Analysis of feature descriptors for IQM
- New features (human perception)
- Visual saliency analysis (eye tracker data)
- New data-driven Image Quality Metric
- New synthetic dataset
- Optimization of parameters of existing metrics

Future Work

- Saliency maps
- More training images
- Other supervised learning techniques
- No-reference metric [Herzog et al., EUROGRAPHICS'12]

Thank You For Your Attention

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http://www.mpi-inf.mpg.de/resources/hdr/metric/

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