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An updated perceptual evaluation of state-of-the-art TMOs

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Motivation

In the present study, we designed three different psychophysical experiments **to study the performance of nine tone-mapping operators** (TMOs). Crucially, these three experiments permitted us to compare (1) the digitally-generated images (a.k.a., tone-mapped images) between each other, and (2) these **tone-mapped images against the real HDR scene**. The obtained data sets facilitated **the construction of three different rankings**, evaluating grayscale and intrinsic image properties conservation, faithfulness to reality, and aesthetic appeal.

Methods

Participants

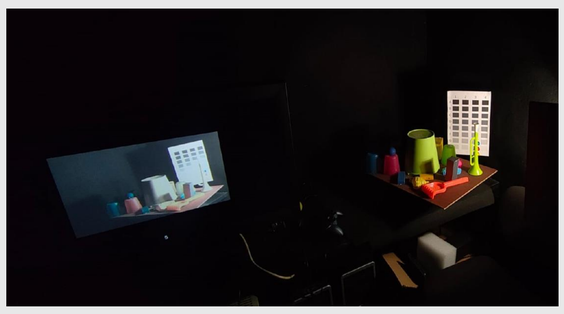
The three tasks were completed by 13 different participants (54% of females), aged between 16 and 50 years old, and with normal or corrected-to-normal vision. All of them were completely naïve for experiment's purpose.

TMOs

Initially, 60 different TMOs were considered. Only the ones developed after 2017 were considered, and we could download the source code of nine of them.

Experimental setup

- Four real scenes including objects of different colours and brightness
- Objects were placed at illuminated and shadowed areas
- Real scenes were illuminated with a high intensity light
- Images of real scenes were taken with a calibrated camera and processed by several TMOs
- Both the real scene and the monitor were placed side by side



Overview of experimental setup

Close-up of visual scene

Experiment 1: Segment Matching

Brightness of faces of parallelepiped objects were matched to the patches of the reference table (N = 23 faces)

Design of Segment Matching Experiment for TMO (left) and scene (right)

Experiment 2: Scene Reproduction

Overall rating of tone-mapped images compared to the real scene (10-point Likert scale)

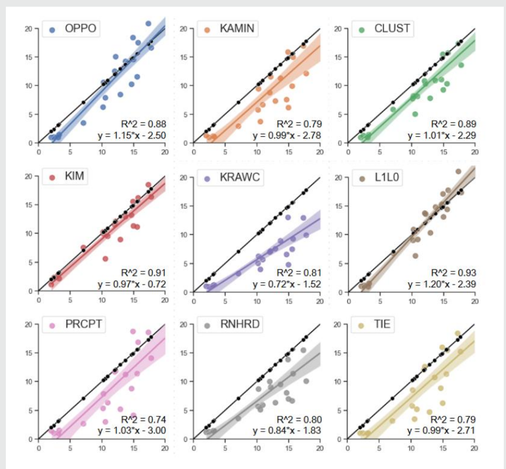
Subjects were advised to focus on details as shadows, colour preservation, sharpness, over/under exposition and overall sensation of realism

Experiment 3: Aesthetics

Overall rating of the aesthetics of the tone-mapped images (10-point Likert scale)

Results

Experiment 1: Segment Matching

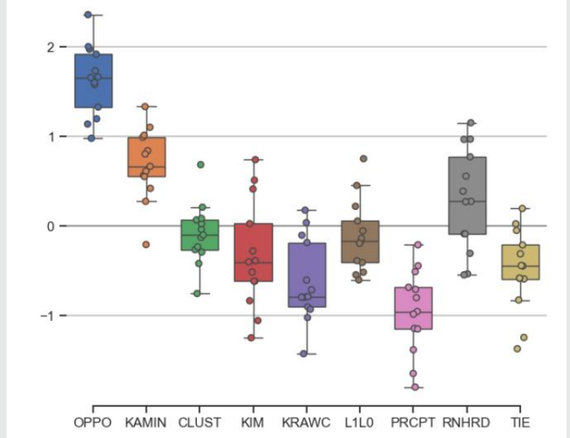


Left: *Segment matching in the real scene (black lines) and in the tone-mapped images (colored lines)*

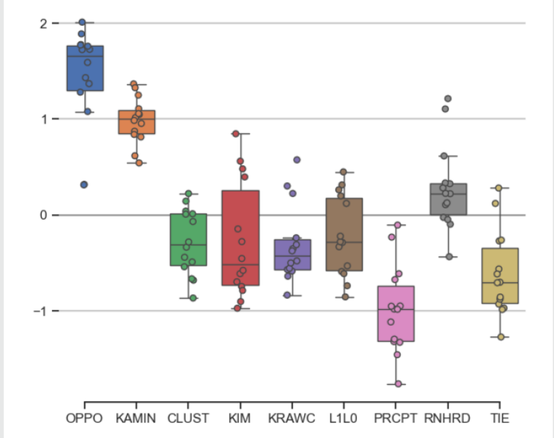
Right: *Summary of linear regression models*
The lower the slope difference and the RMSE, the better

TMO	Slope Difference	RMSE	T-test p-value	R^2	Type
OppoCPH2207	0.149	2.600	0.726	0.880	Modern
Kaminari	**0.012**	4.074	0.108	0.792	Modern
Li2018	**0.011**	2.927	0.225	0.890	Modern
KimKautz	0.027	**2.058**	0.541	0.905	Classic
Krawczyk	0.283	5.613	**0.002**	0.807	Classic
Liang	0.200	**2.122**	0.969	0.933	Modern
Khan2020	0.029	4.315	0.163	0.741	Modern
Reinhard	0.159	4.562	**0.025**	0.797	Classic
Khan2018	**0.011**	4.050	0.117	0.788	Classic

Experiments 2 and 3: Scene Reproduction and Aesthetics



Normalized ratings for Scene Reproduction



Normalized rating for Aesthetics

Spearman correlation

Conclusions

On one hand, in recent years, tone-mapping operators have significantly improved in terms of perceptual quality. Their results, particularly in scene reproduction and aesthetics, suggest that developers have prioritized these aspects. On the other hand, classical tone-mapping operators aimed to preserve local relationships between objects, which does not appear to strongly affect scene reproduction or aesthetics.

Nonetheless, there is still considerable room for further perceptual enhancements in tone-mapping operators.

Acknowledgments

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