SFB-TRR 161
Quantitative Methods for Visual Computing
Transregional Collaborative Research Center

Subjective Image Quality Assessment with Boosted Triplet Comparisons

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Full Reference IQA Datasets

IQA Datasets	Distortion Levels
CID:IQ	5
CSIQ	3-5
LIVE	5-6
KADID-10k	5
TID2013	5
VCL@FER	6

Qualities range over the five ACR/DCR categories.

Are 5-6 distortion levels enough?

No: Content providers apply image compression, focus on the high quality range (approx. 1 JND).

To create datasets with 12 or more distortion levels up to 2 or 3 JND, we need to sharpen the subjective assessment (DCR).

Our proposal: **Boosted triplet comparisons**.

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Reference and Distorted Image

Ref.

Orig. Dist.

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Boosting (A)

$$v' = v_{ref} + \alpha(v_{dist} - v_{ref}) \quad (\alpha>1)$$

Ref.

Amplification (A)

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Boosting (A+Z)

Ref.

Added Zoom (Z)

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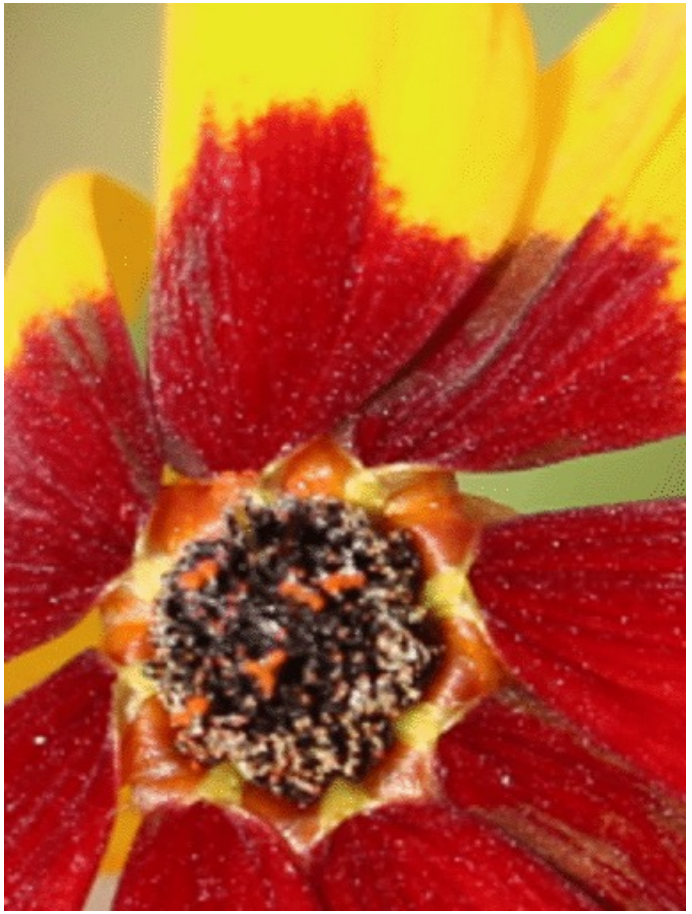
Boosting (A+Z+F)

Ref.



Added Flicker (F)

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Triplet Comparisons (TC)

pivot

Which image is more similar to the middle one ?

left | not sure | right

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Thurstonian Scale Reconstruction from TC

$$Z_{ijk} = |X_k - X_j| - |X_i - X_j|$$

$$\begin{aligned}\Pr(Z_{ijk} > 0 \,|\, \boldsymbol{\mu}) &= 1 - \Phi(\mu_k - \mu_i) - \Phi\left(\frac{\mu_k + \mu_i - 2\mu_j}{\sqrt{3}}\right) \\ &\quad + 2\,\Phi(\mu_k - \mu_i)\,\Phi\left(\frac{\mu_k + \mu_i - 2\mu_j}{\sqrt{3}}\right) \\ \Pr(Z_{ijk} \le 0 \,|\, \boldsymbol{\mu}) &= 1 - \Pr(Z_{ijk} > 0 \,|\, \boldsymbol{\mu}).\end{aligned}$$

$$\begin{aligned}L(\boldsymbol{\mu}) &= -\sum_{(i,j,k,R_{ijk}) \in T} \log p^{R_{ijk}} (1-p)^{1-R_{ijk}} \\ p &= \Pr(Z_{ijk} > 0 \,|\, \boldsymbol{\mu}).\end{aligned}$$

$$\hat{\boldsymbol{\mu}} = \underset{\boldsymbol{\mu}=(\mu_0,\ldots,\mu_M)}{\arg\min} \; L(\boldsymbol{\mu}).$$

Algorithm 2 Probability of a response $R_{ijk} \in \{0,1\}$ to a triplet comparison (i,j,k)

$\boldsymbol{\mu} = (\mu_0, \ldots, \mu_M)$ ▷ stimuli means in model
$u_0 \leftarrow \mu_k - \mu_i$
$v_0 \leftarrow (\mu_k + \mu_i - 2\mu_j)/\sqrt{3}$
$p \leftarrow 1 - \Phi(u_0) - \Phi(v_0) + 2\Phi(u_0)\Phi(v_0)$
if $R_{ijk} = 1$ **then** ▷ stimulus i closer to j than k
    Return p
else ▷ stimulus k closer to j than i
    Return $1 - p$

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Three Experiments

1. Basic triplet comparisons
   (only the reference image as the pivot)

2. General triplet comparisons
   (arbitrary image as the pivot)

3. Boosting for degradation category rating (DCR)

Implemented by crowdsourcing on AMT.

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Materials

- 10 source images from the MCL-JCI Dataset

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Materials

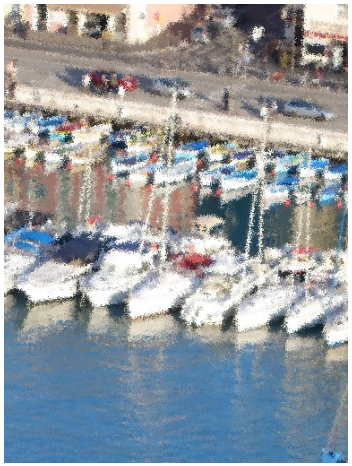
- 7 Distortion Types

Ref.

Color Diffusion

High Sharpen

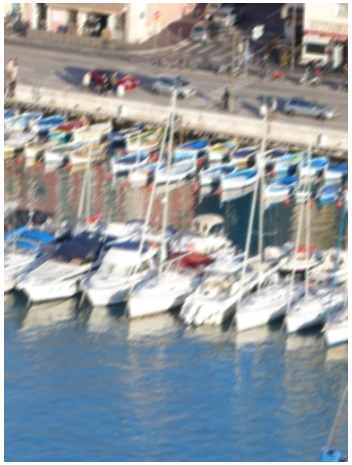
Jitter



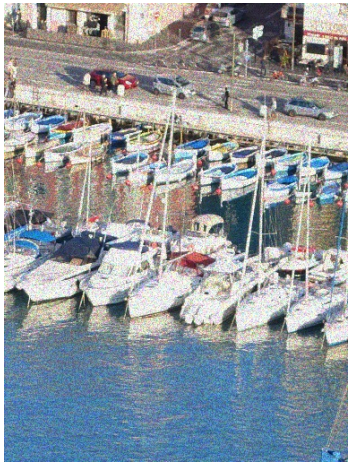
JPEG 2000

Lens Blur

Motion Blur



Multiplicative Noise



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Experiment I (Baseline TC)

- 8 types of baseline TCs (pivot: reference image)
- 10 sources
- 7 distortion types
- **13** distortion levels (1 ref. + 12 dist.) ~ 3 JND
- Spacing between consecutive test images: **0.25** JND

Left Ref. Right

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Type 1/8 of Baseline TCs

- Plain TC (Original)

Left Ref. Right

Which image is more similar to the middle one ?

left not sure right

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Type 2/8 of Baseline TCs

- A-Boosting (Amplified)

$$v' = v_{ref} + \alpha(v_{dist} - v_{ref}) \quad (\alpha=2)$$

Left Ref. Right

Which image is more similar to the middle one ?

left not sure right

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Type 3/8 of Baseline TCs

- Z-Boosting (cropped to 0.5x → Zoomed 2x)

Left Ref. Right

Which image is more similar to the middle one ?

left not sure right

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Type 5/8 of Baseline TCs

- AZ-Boosting (Amplified + Zoomed)

Left Ref. Right

Which image is more similar to the middle one ?

left not sure right

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Type 5/8 of Baseline TCs

- F-Boosting (Flicker)

Left (←→Ref.) Right (←→Ref.)

Which image has a stronger flicker effect?

left | not sure | right

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Type 6/8 of Baseline TCs

- AF-Boosting (Amplified + Flicker)

Left (←→Ref.) Right (←→Ref.)

Which image has a stronger flicker effect?

left not sure right

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Type 7/8 of Baseline TCs

- ZF-Boosting (Zoomed + Flicker)

Left (←→Ref.) Right (←→Ref.)

Which image has a stronger flicker effect?

left not sure right

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Type 8/8 of Baseline TCs

- AZF-Boosting (Amplified + Zoomed + Flicker)

Left (←→Ref.) Right (←→Ref.)

Which image has a stronger flicker effect?

left not sure right

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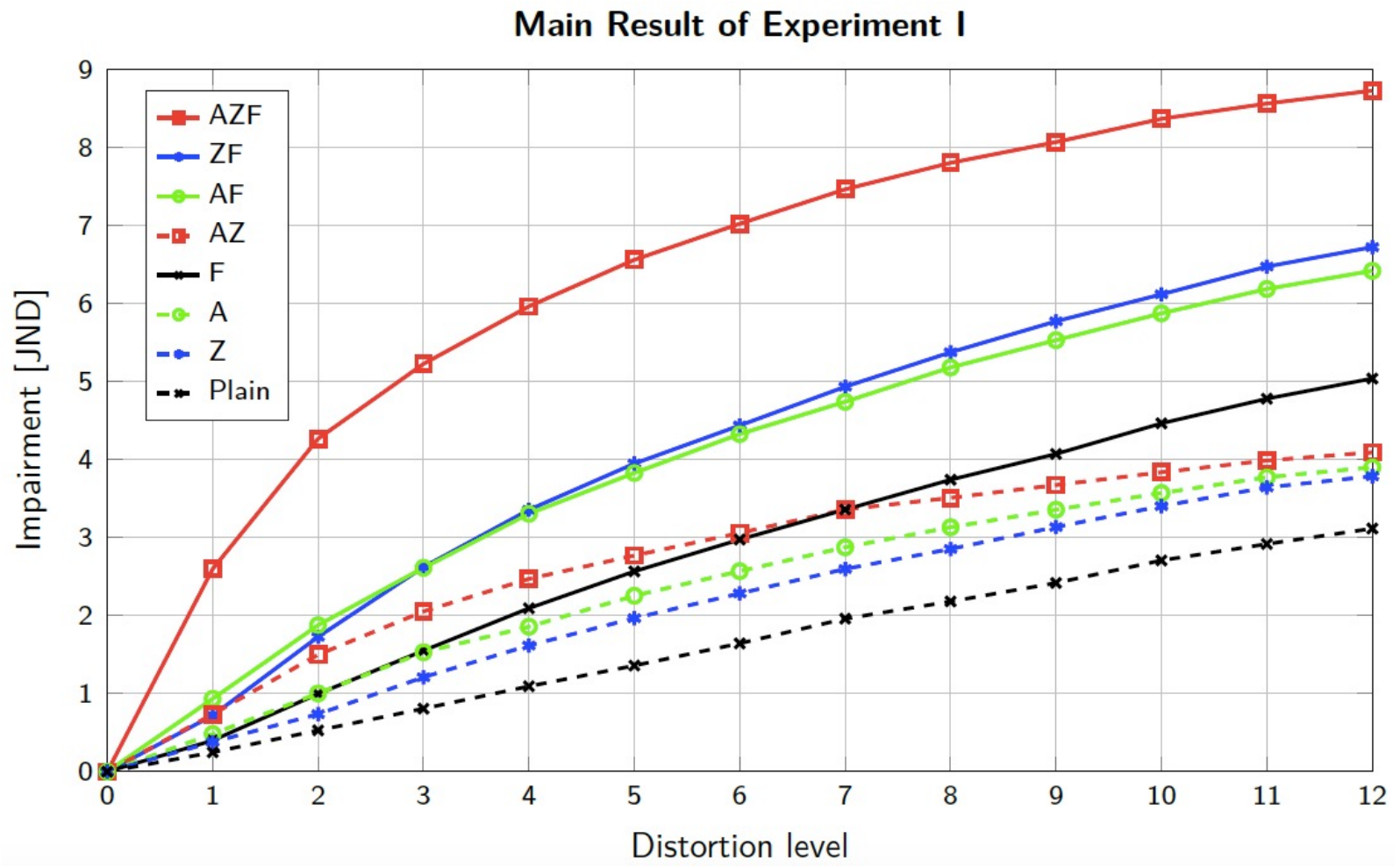
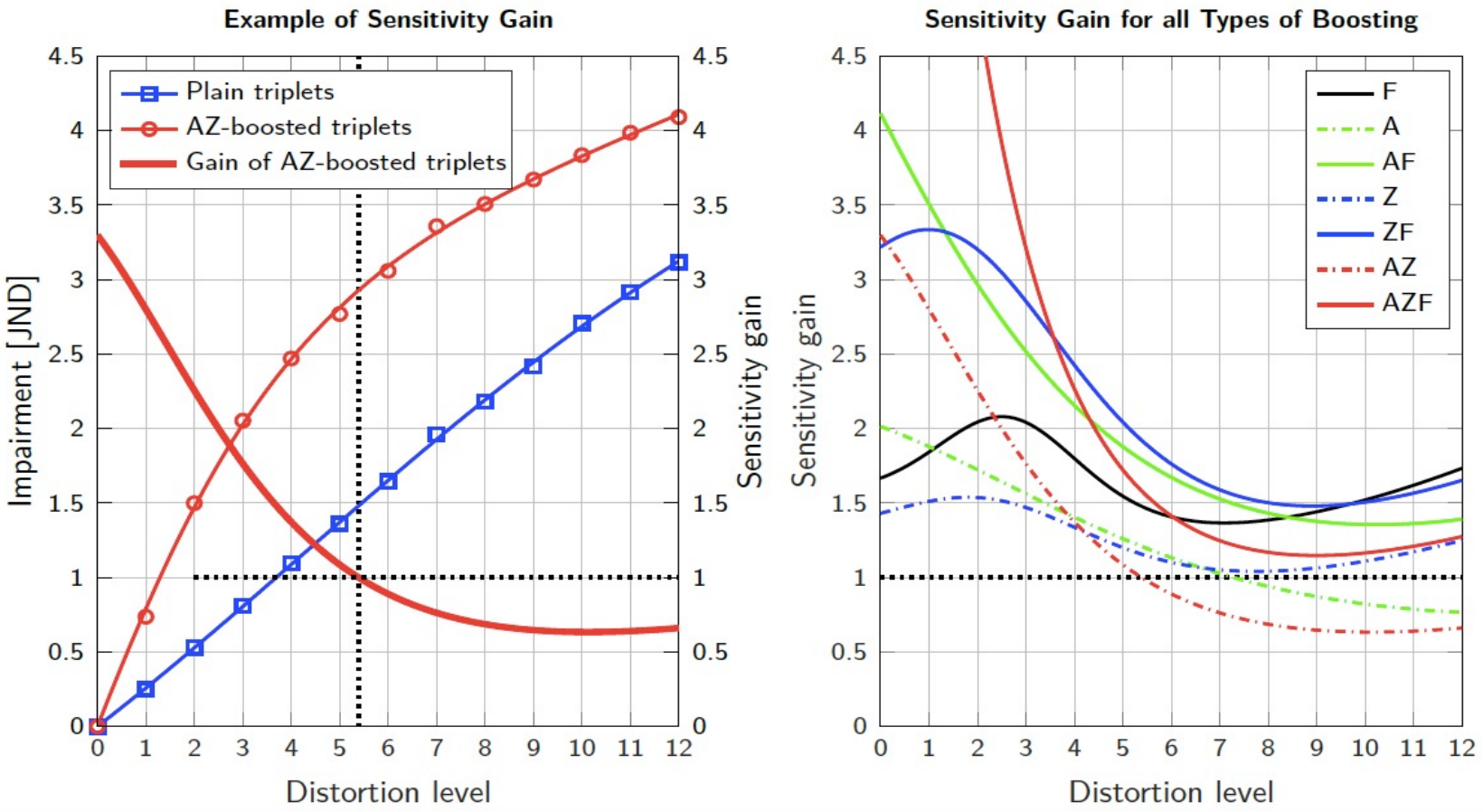
1. Reconstructed Impairment Scales



2. Sensitivity Gain



Sensitivity gain: Factor by which an increase of perceived distortion is multiplied by boosting.

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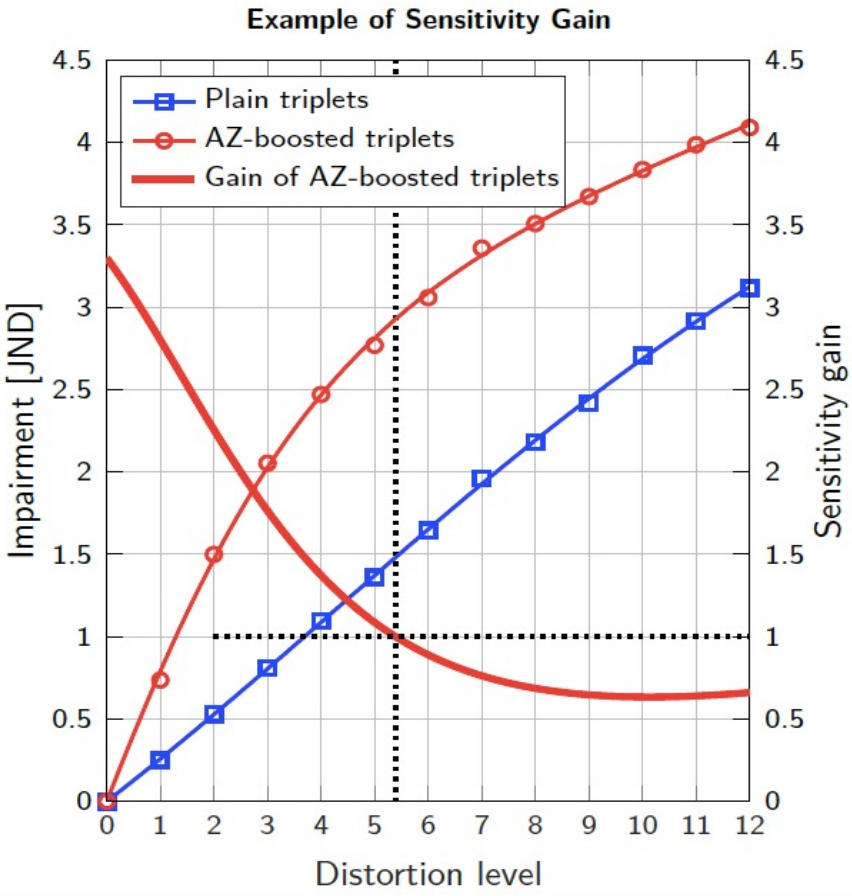
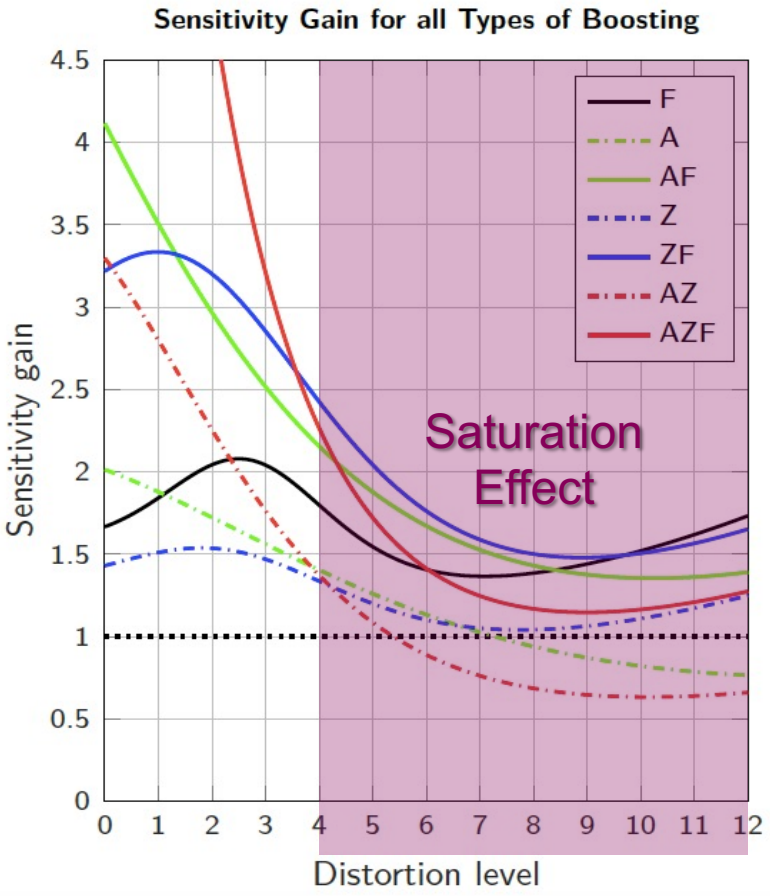
2. Sensitivity Gain





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Experiment II (General TC)

- 2 types of general TCs (pivot: distorted image)
  - plain
  - AZF-boosting
- 10 sources
- 1 distortion type (motion blur)
- **31** distortion levels (1ref. + 30 dist.) ~ 3 JND
- Spacing between consecutive test images: **0.1** JND

Left Dist. Right

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2 Types of General TCs

- Plain TC (original)

Left Dist. Right

Which image is more similar to the middle one ?

left not sure not sure

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2 Types of General TCs

- AZF-Boosting (Amplified + Zoomed + Flicker)

Left (←→Dist.) Right (←→Dist.)

Which image has a stronger flicker effect?

left not sure not sure

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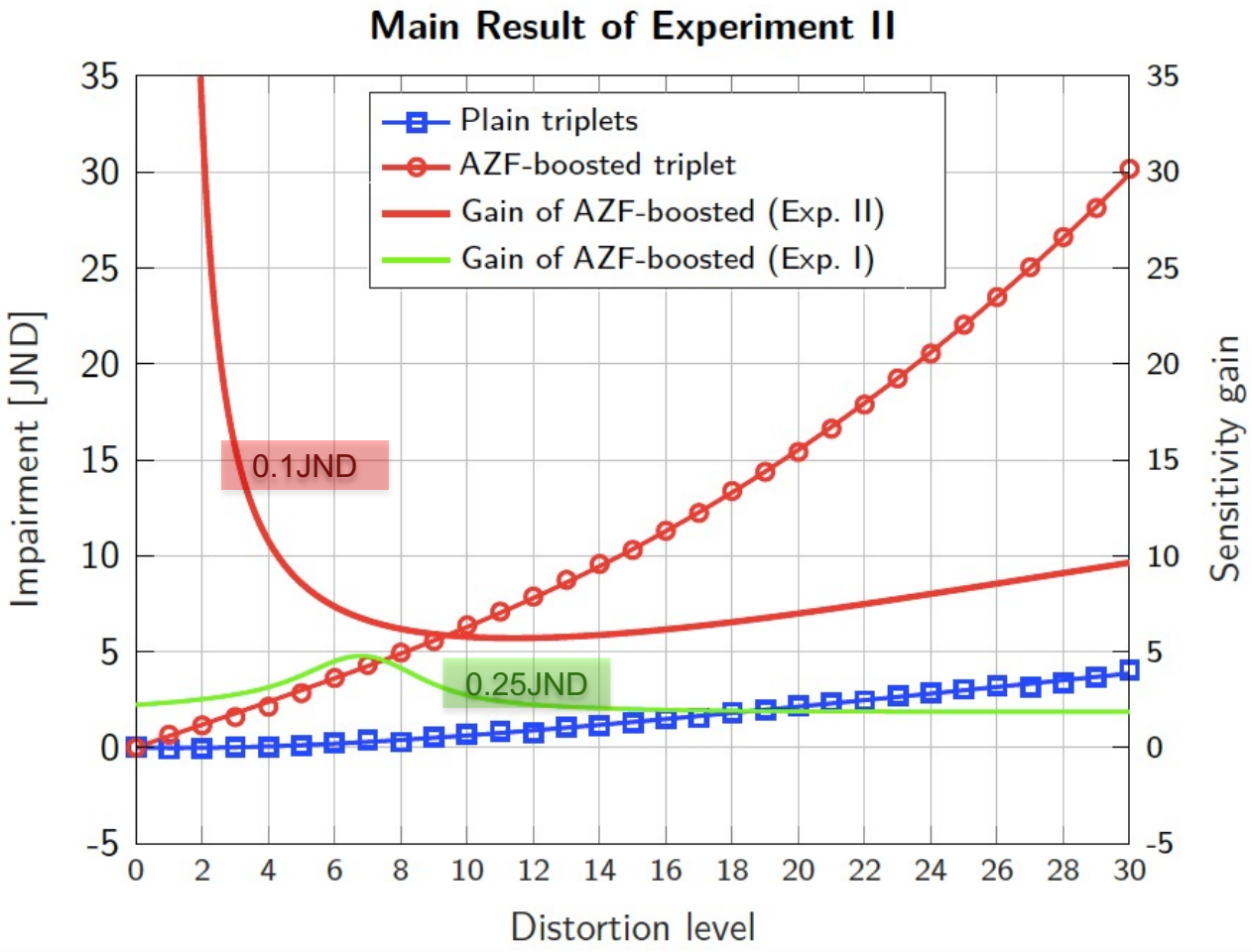
1. Impairment Scales & Sensitivity Gain



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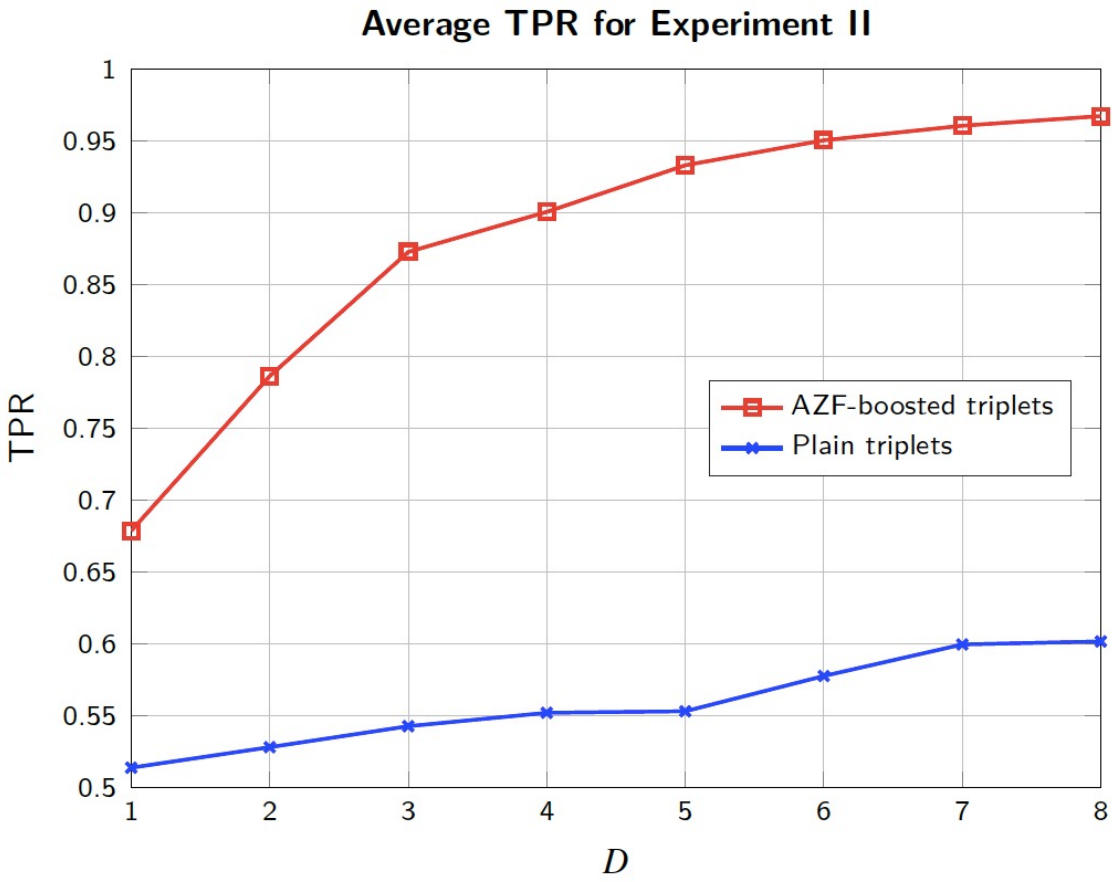
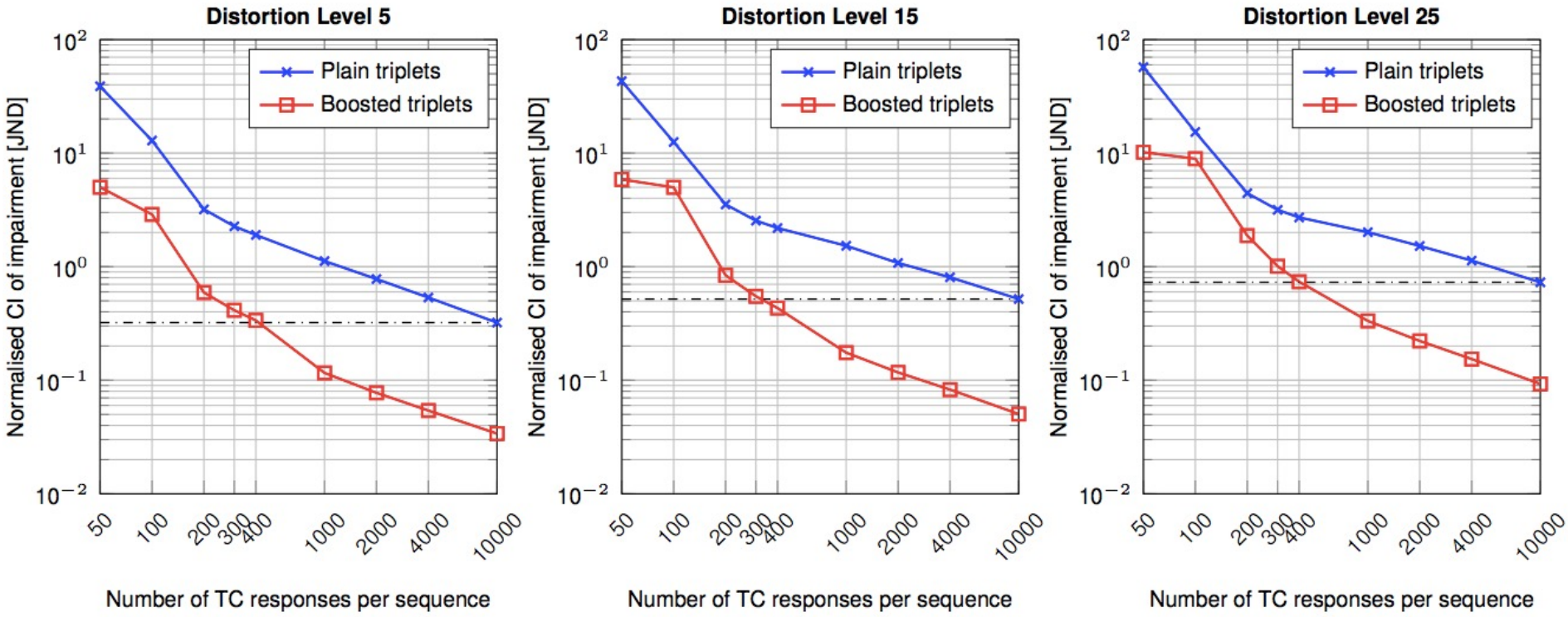
2. True Positive Rate



Average TPR for all triplets (i, j, k) and distance D = ||i-j|-|j-k|| for all 10 sources

3. Convergence in Precision

- The precision of the reconstructions for given budgets of TCs
- 95% confidence intervals (CI)



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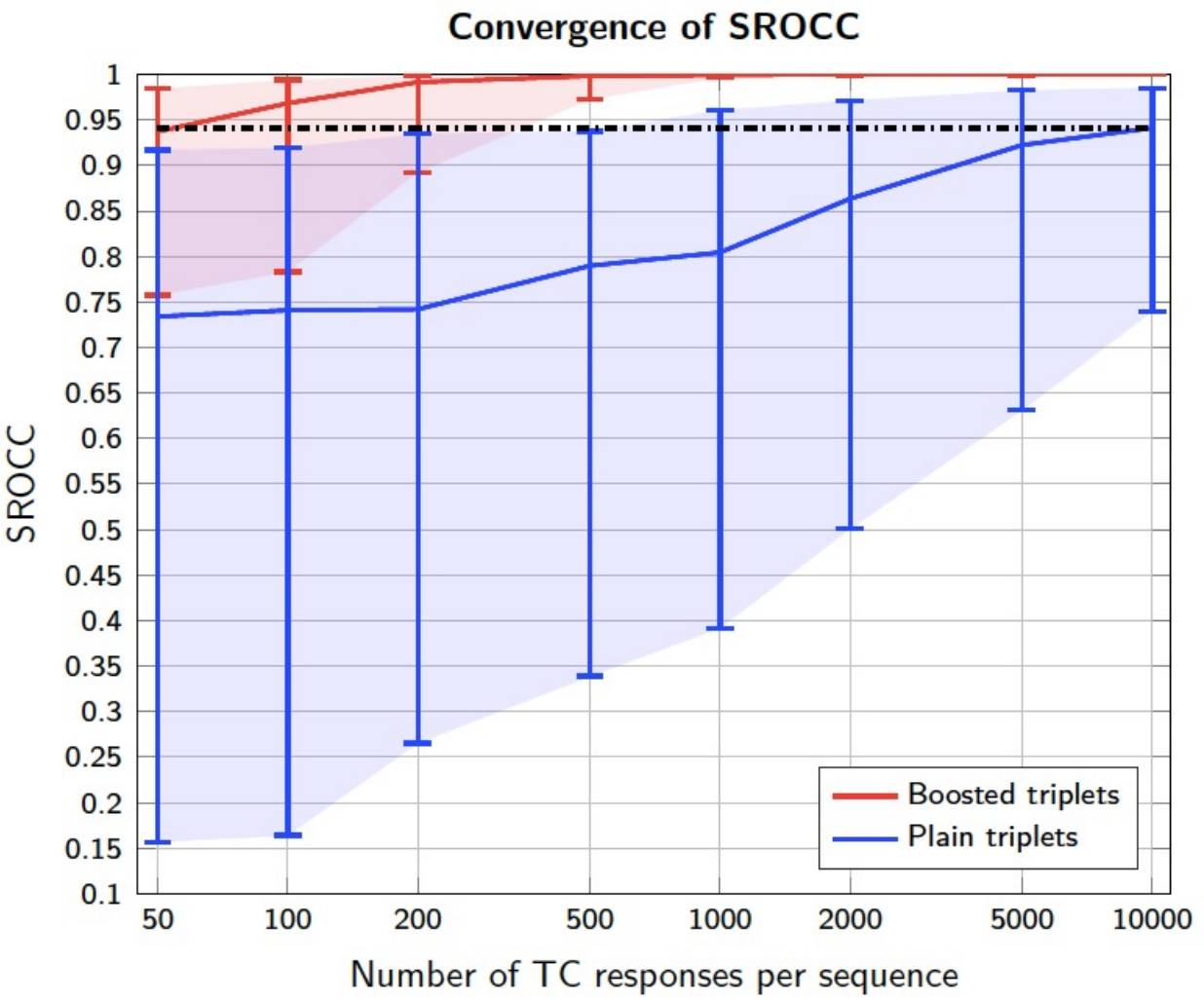
4. Convergence in Ordering



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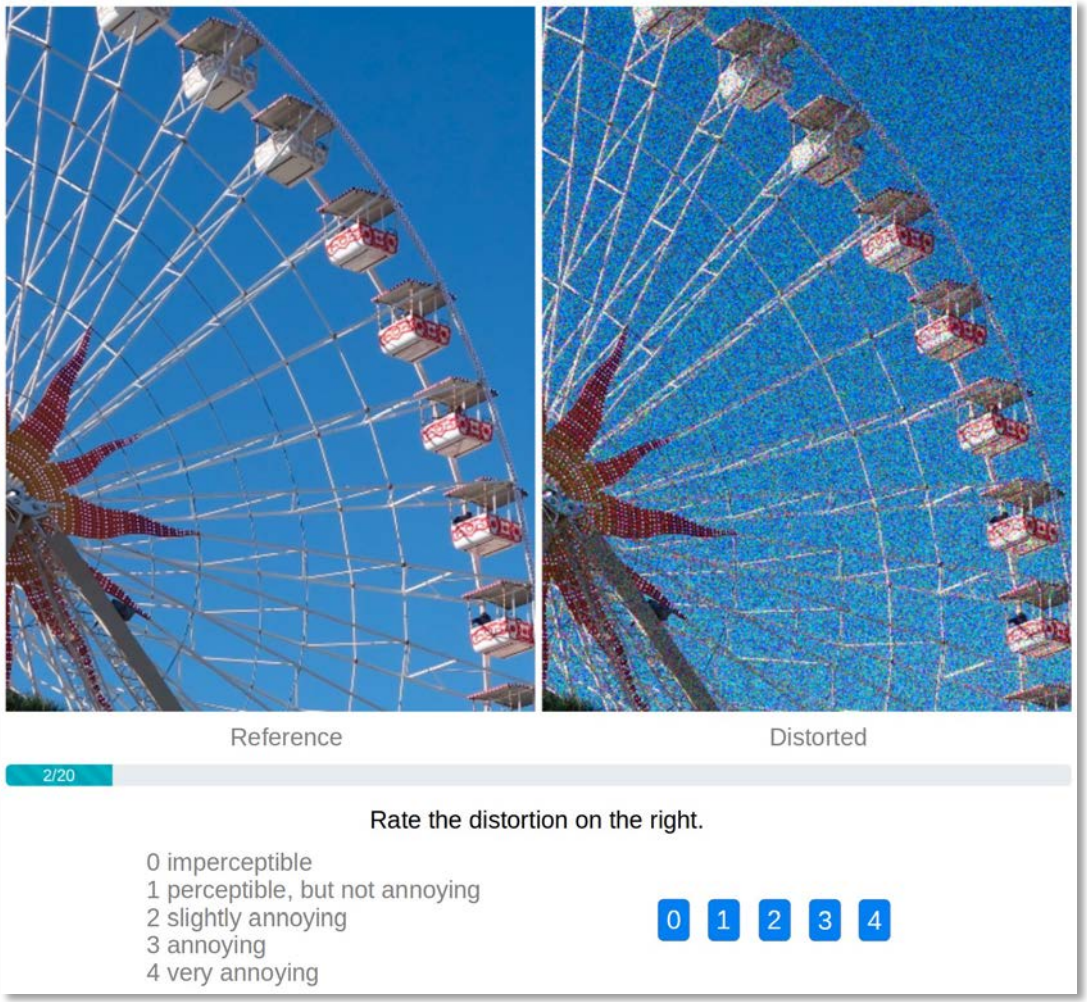
Experiment III (DCR)

- 4 types of DCRs (Plain, A, Z, AZ)
- 10 sources
- 7 distortion types
- 13 distortion levels
  (1 ref. + 12 dist.) ~ 3 JND
- Spacing between consecutive images: 0.25 JND



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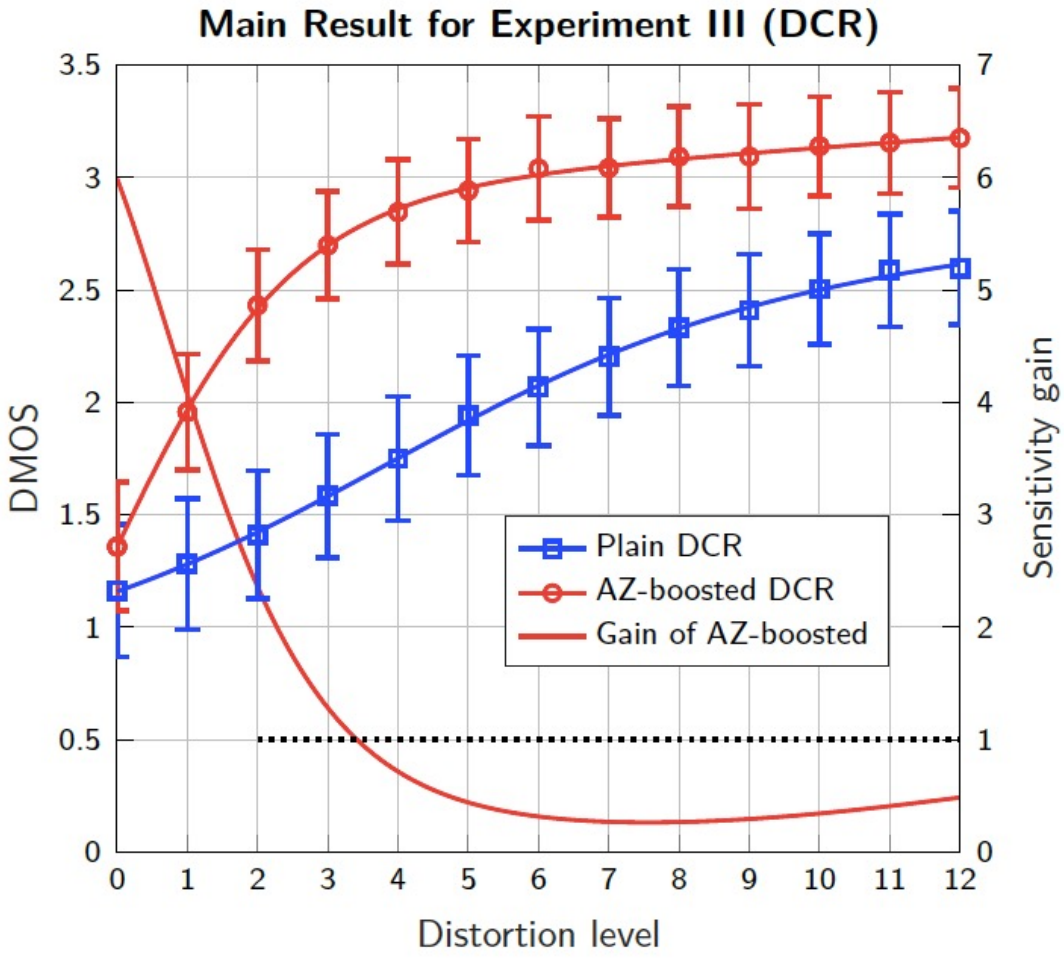
Result of Experiment III (DCR)



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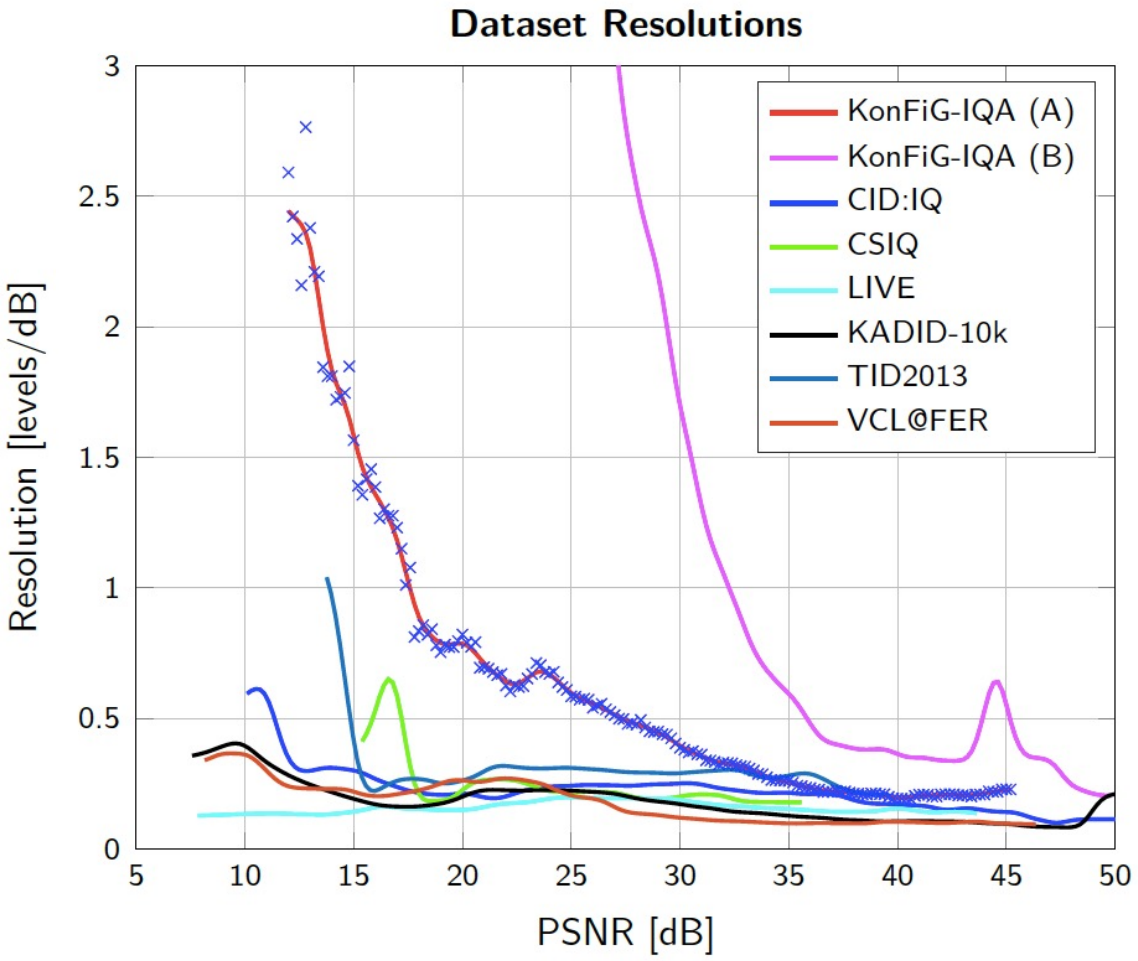
KonFiG-IQA

- Konstanz **Fine-Grained** IQA Dataset

IQA Datasets	Distortion Levels
CID:IQ	5
CSIQ	3-5
LIVE	5-6
KaDiD-10k	5
TID2013	5
VCL@FER	6
KonFiG-IQA (A)	12
KonFiG-IQA (B)	30



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Conclusion

1. Three boosting strategies: artefact amplification, zooming, flicker
   - enlarge the sensitivity of pair and triplet comparisons
   - increase the accuracy of subjective FR-IQA
2. Reconstruction of perceptual qualities from triplet comparisons
   - Thurstone‘s probabilistic model
   - maximum likelihood estimation
3. Two IQA datasets of 1140 images
   - 10 reference images, 7 dist. types, 12/30 dist. levels over 3 JND
   - 1.7 million crowdsourcing responses to triplet comparisons
4. Extensive FR-IQA performance analysis of boosted triplet comparisons
   - ratio of true positive responses
   - detection rates
   - sensitivity gains
   - effect sizes
   - convergence in accuracy
   - convergence in correlation
   - time complexity

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