SQAD: Automatic Smartphone Camera Quality Assessment and Benchmarking – Supplementary Material –

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1. Dataset Overview

Here we provide the complete quality factor measurement results of our SQAD dataset in Tab. 5. Reported factor results are the measurement average of 9 images. Specially, in PSF we apply four horizontal and four vertical patterns to compute the average. The illuminance level for noise and dynamic range measurement in the dark room is nearly 0 lux before applying the OLED screen, while for the remaining patterns the illuminance level is approximately 1000 lux.

2. Methods and Theorems

Resolution Measurement. We summarize the algorithm applied to evaluate the resolution in Algorithm 1.

Algorithm 1: Resolution from wedge pattern

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Result: resol in LW/PH
Pattern range initialization: L = [L_min, L_max];
1. Detect whole pattern with thresholding;
2. Indices mark (black line) finding: IdxBars;
for i to numbers of contours do
    if Ratio_{W/H}(i) ∈ Range then
        IdxBars ← BoundingBox(i)
    end
end
sort(IdxBars) according to y coordinate;
3. Detect wedge region: filtering + edge detection;
4. Initialize every wedge component's center: arrC;
5. Track centers with interval updates;
   Interval interv = mean(max_arrC − min_arrC);
for loc ← 1 to H_wedge do
    foreach element e of the centers do arrC(e) ←
      FindNewPeak(loc);
    update interv with new centers;
    if MinPeakProminence(loc) < 2 then
        break;
    end
end
resol = transformed(loc) with IdxBars and L;
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CIEDE2000 color difference formula. We simply refer to the formula from [3] (as in Eq. (3)) in where five important corrections are included to solve perceptual uniformity:

$$\Delta E_{00}^{12} = \sqrt{(\frac{\Delta L'}{k_L S_L})^2 + (\frac{\Delta C'}{k_C S_C})^2 + (\frac{\Delta H'}{k_H S_H})^2 + R_T \frac{\Delta C'}{k_C S_C} \frac{\Delta H'}{k_H S_H}} \quad (3)$$

with parametric weighting factors k_L, k_C and k_H, the chroma difference $\Delta C'$, the hue difference $\Delta H'$, and $\Delta L = L_2 - L_1$. All the other terms are computed from two CIELAB color values $\{L_1, a_1, b_1\}$ and $\{L_2, a_2, b_2\}$. More calculation details are provided in their original paper [3].

Dynamic Range Measurement. The scene SNR is calculated using Eq. (4) and Eq. (5), and is determined by scaling the ISO SNR with a factor. $\sigma_{f_{stop}}$ in Eq. (4) is the scene noise in logarithmic units of f-stops:

$$\begin{aligned} \sigma_{f_{stop}} &= \frac{\sigma}{dpixel/df_{stop}} = \frac{\sigma}{dpixel/d\log_2 L} \\ &= \frac{\sigma}{\ln(2) * L * dpixel/dL} \cong \frac{\sigma}{L * dpixel/dL} \end{aligned} \quad (4)$$

where scene luminance L (or exposure) is the signal level of the scene, and there is a relationship between different units: 1 f-stop = 6.02 dB = $\log_2 L$. Then, the scene noise and SNR can be expressed by Eq. (5). It finally leads to SNR$_{scene}$ = $\ln(2)$ SNR$_{ISO}$.

$$\begin{aligned} \sigma_{scene} &= \frac{\sigma}{dpixel/dL} \cong \sigma_{f_{stop}} * L \\ SNR_{scene} &= \frac{L}{\sigma_{scene}} = \frac{1}{\sigma_{f_{stop}}} \end{aligned} \quad (5)$$

To enable a representation directly from signals and noise in pixels, [1] further introduces scene-referenced noise and SNR in Eq. (6). The equivalence between SNR$_{scene}$ and SNR$_{ref}$ establishes a connection between pixel noise and scene noise which cannot be measured directly. It is the calculation basis for [1].

$$\begin{aligned} \sigma_{ref} &= \frac{\sigma}{dpixel/dL} \cdot \frac{pixel}{L} \\ SNR_{ref} &= \frac{pixel}{\sigma_{ref}} = \frac{L}{\sigma/(dpixel/dL)} = SNR_{scene} \end{aligned} \quad (6)$$

Table 5: *Overview of our data collection.* Our dataset comprises of 29 different devices reflects the development of smartphone photography over the last decades. Note, for some devices definite image sensor models were not available (-).

No.	Name	*Device Specifications*			*Sensor Quality Factors*					
		Year	Image Size	Sensor	Resolution	Color Accuracy	Noise	Dynamic Range	PSF	Aliasing
1	ASUS Z00AD	2015	4096*3072	T4K37	8.57	947.94	3.7912	6.6438	68.3	0.0699
2	CANON EOS70D	2013	3648*2432	-	29.22	745.74	1.8789	9.6336	17.8	0
3	Google Pixel 2	2017	4032*3024	IMX362	13.77	684.54	2.6599	7.6404	27.5	0.0746
4	Google Pixel 6	2021	4080*3072	ISOCELL GN1	11.95	637.27	2.5658	7.6404	39.5	0.0965
5	HTC DesireEye	2014	4208*2368	IMX214	12.59	915.51	4.064	6.3117	59.6	0.0717
6	HTC One (M7)	2012	2688*1520	VD6869	5.7	952.16	6.2865	5.9795	54.5	0.2931
7	HTC One X+	2012	3264*1840	-	7.48	902.7	2.6295	6.3117	56.3	0.0996
8	HUAWEI P8Lite	2015	4160*3120	IMX214	10.62	474.78	3.4722	7.3082	62.4	0.077
9	HUAWEI P30Pro	2019	3648*2736	IMX600y	26.71	706.83	1.4529	8.637	22.5	0.0841[2]
10	LG G3	2014	4160*3120	IMX135	16.66	902.93	12.0148	7.6404	70.3	0.07
11	Nexus 6	2014	4160*3120	IMX214	11.1	531.27	1.7157	7.6404	64.8	0.086
12	Nokia asha300	2011	2592*1944	-	7.88	897.55	5.2513	6.976	51.6	0.0827
13	Nokia N79	2008	2592*1944	-	8.56	795.29	4.0134	6.976	65.7	0.122
14	OPPO A92S	2020	4000*3000	IMX586	9.57	905.39	1.8599	6.6438	51.5	0.0827
15	Realme X7Pro	2020	4608*3456	IMX686	10.45	736.32	2.6861	6.6438	50.0	0
16	Samsung GalaxyNote20 Ultra5G	2020	4000*3000	ISOCELL HM1	11.74	736.91	1.7211	7.3082	52.5	0.0908
17	Samsung Galaxy S4	2013	4128*2322	IMX091PQ	13.33	838.65	2.0311	6.976	52.7	0.0734
18	Samsung Galaxy S5	2014	5312*2988	ISOCELL 2P2	14.33	806.69	4.624	6.976	48.0	0.0567
19	Samsung Galaxy S6 edge	2015	5312*2988	IMX240/ISOCELL 2P2	12.9	863.93	3.1192	6.976	51.0	0.0624
20	Samsung Galaxy S10	2020	4032*2268	ISOCELL 2L4	18.64	712	2.9899	7.3082	24.4	0
21	Samsung GT-I9100	2011	3264*2448	ISOCELL 3H2	8.19	931.12	2.5423	6.6438	79.0	0.0925
22	Samsung GT-I9300	2012	3264*2448	ISOCELL 3H2	9.64	876.85	3.3558	7.3082	64.5	0.0944
23	Sony Ericsson T630	2003	640*480	-	2.15	862.57	10.1393	5.9795	168.7	0.3904
24	Sony Ericsson vivaz	2010	3264*1836	-	10.56	984.92	1.8174	6.976	48.4	0.1082
25	Sony Ericsson W810	2006	1632*1224	-	6.14	868.28	2.6588	6.3117	138.8	0.2865
26	Sony st21i	2012	2048*1536	-	3.33	757.66	2.884	6.976	87.8	0.1616
27	Sony Xperia XA1Ultra	2017	5520*4144	IMX300	11.06	658.05	1.5321	7.6404	58.0	0
28	Sony Xperia Z5Compact	2015	3840*2160	IMX300	13.41	773.8	3.6219	5.3151	46.9	0.0708
29	Sony Xperia Z	2013	3920*2204	IMX135	9.96	950.31	2.2291	5.9795	48.3	0.0692

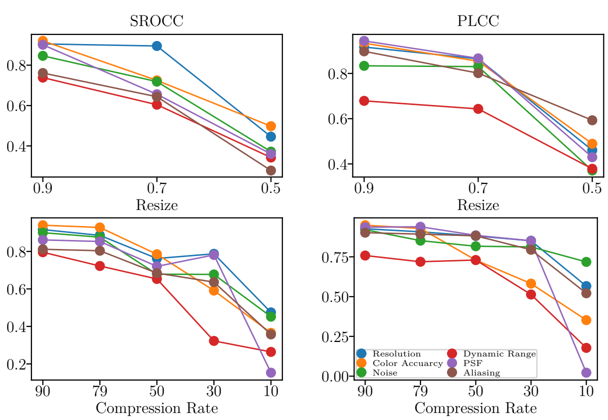


Figure 6: *Results on image quality degradation for ResNet50 [2] model.* We include JPEG lossy compression and image resizing as degradations. Results are multi-crop (16×) predictions.

We apply the above equations in DR measurement process and the results are expressed in SNR with f-stop units. Considered indicators exhibit considerable independence from image signal processing and flare light-induced fogging, which is excellent for real-world camera performance.

3. Visualizations

We provide examples captured with different cameras from our SQAD dataset in Fig. 7.

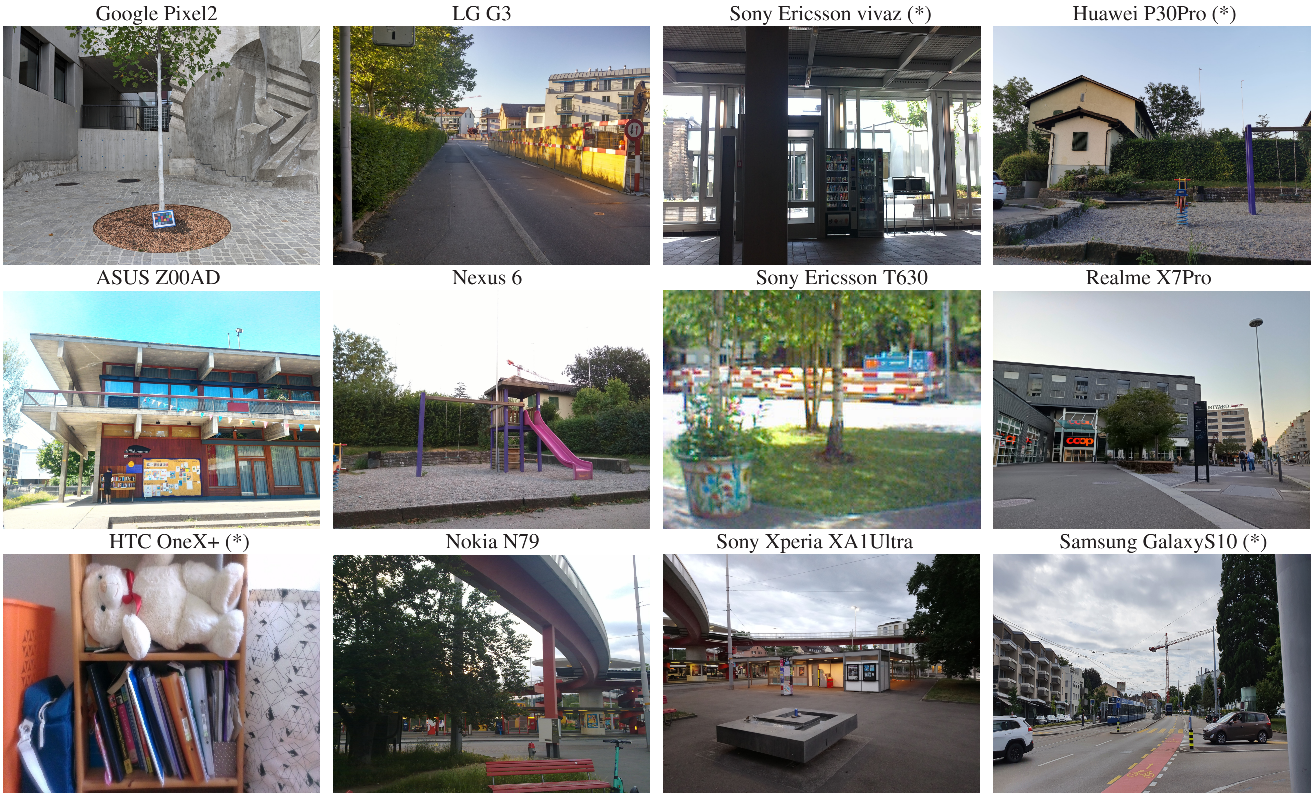
In addition to the ablations in the main text, we also illustrate a regression analysis for various image degradation settings in Fig. 6. Under the same compression rate or resize ratio with ResNet50 backbone, the trained model achieves SROCC/PLCC scores > 0.6 on the test set if distortions are not severe, which proves the ability to tolerate some image degradations. In practice, impairment levels may vary across different photos on the Internet, and we will investigate this further in future works.

References

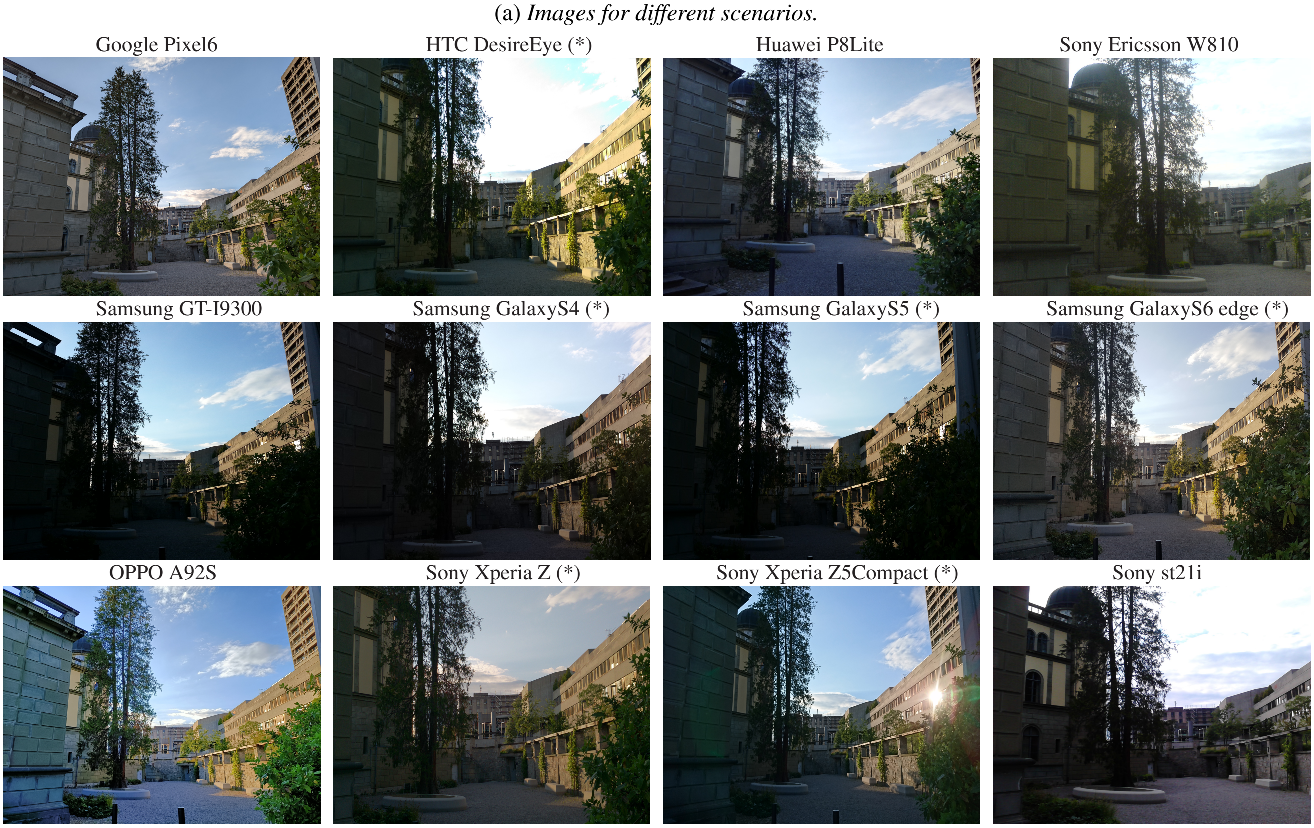
[1] Imatest: Solutions on image quality factors. https://www.imatest.com/solutions/iqfactors/. 1

[2] Kaiming He, Xiangyu Zhang, Shaoqing Ren, and Jian Sun. Deep residual learning for image recognition. In *Proceedings of the IEEE conference on computer vision and pattern recognition*, pages 770–778, 2016. 2

[3] Gaurav Sharma, Wencheng Wu, and Edul N Dalal. The ciede2000 color-difference formula: Implementation notes, supplementary test data, and mathematical observations. *Color Research & Application: Endorsed by Inter-Society Color Council, The Colour Group (Great Britain), Canadian Society for Color, Color Science Association of Japan, Dutch Society for the Study of Color, The Swedish Colour Centre Foundation, Colour Society of Australia, Centre Français de la Couleur*, 30(1):21–30, 2005. 1



(a) *Images for different scenarios.*



(b) *Images for the same scenario.*

Figure 7: *Examples images taken from SQAD dataset.* Images taken with devices marked by asterisks (*) are resized for visualization. The image taken with *Sony Ericsson T630* portrays the same scene as in Fig. 2 of the main text.