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VCX: An industry initiative to create an objective camera module evaluation for mobile devices

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Abstract

Due to the fast evolving technologies and the increasing importance of Social Media, the camera is one of the most important components of today's mobile phones. Nowadays, smartphones are taking over a big share of the compact camera market. A simple reason for this might be revealed by the famous quote: "The best camera is the one that's with you". But with the vast choice of devices and great promises of manufacturers, there is a demand to characterize image quality and performance in very simple terms in order to provide information that helps choosing the best-suited device. The current existing evaluation systems are either not entirely objective or are under development and haven't reached a useful level yet. Therefore the industry itself has gotten together and created a new objective quality evaluation system named Valued Camera eXperience (VCX). It is designed to reflect the user experience regarding the image quality and the performance of a camera in a mobile device. Members of the initiative so fare are: Apple, Huawei, Image Engineering, LG, Mediatec, Nomicam, Oppo, TCL, Vivo, and Vodafone.

Introduction

Why another mobile camera evaluation standard? In fact the basis for VCX existed way before CPIQ or DxOMark. In the early 2000 Vodafone as one of the main carriers in Europe looked into the quality of cellphones, which they bundled with their contracts. One of the important parts of these phones were and still are the cameras. So Vodafone decided to define KPIs (key performance indicators) based on ISO standards to assess the quality of cell phone camera modules. To define the KPIs Vodafone needed to get a feeling about the camera performance and consulted Image Engineering to get some guidance and to help with tests.

In 2013 Vodafone decided to take the KPIs to the next level. Cameras in cell phones had outgrown the former KPIs and a lot of new technologies had been implemented. Therefore an update was needed and Vodafone asked Image Engineering to update the physical measurements in order to get a complete picture of the camera performance. In the background Vodafone worked on converting the physical measurements into an objective quality rating system. At that time the system was called Vodafone Camera eXperience. In 2015 the system was updated according to the latest ISO standards and in 2016 Vodafone and Image Engineering decided that due to a lack of resources within Vodafone that Image Engineering should make the system public and move it forward under the neutral name Valued Camera eXperience. This was done at Photokina in Cologne in September 2016. The feedback and interest from the industry was so good that in late 2016 the idea was born to make this an open industry standard managed by the industry. So in March 2017 a conference was held in Duesseldorf and the decision was made to found a non profit organization named VCX-Forum e.V.

Today VCX-Forum e.V. has X members that decide on the path forward in the future.

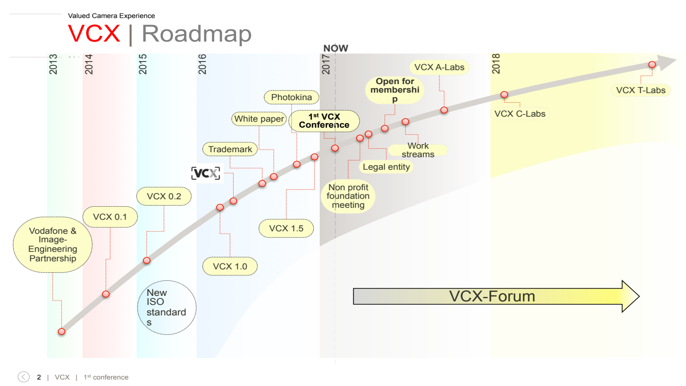

Figure 1: The VCX roadmap.

VCX is based on 5 tenets which guarantee results that can be mapped to real life experience

1. VCX measurements shall ensure out-of-the-box experience
2. VCX shall remain 100% objective
3. VCX shall be open and transparent
4. VCX shall employ/use an independent imaging lab for testing
5. VCX shall seek continuous improvement

Tenet 1. (VCX measurements shall ensure out-of-the-box experience): This tenet dictates that the device under test shall be obtained from an unbiased/untainted source i.e., a random sample/s from a store that sells the device under test. This ensures that neither special samples from suppliers nor custom hardware/software are accepted. The results are obtained from a device that is launched onto the market. The device is tested using the default camera application and setting (except for flash test cases). If a need arises due to market forces and/or user demand that a device result be published at launch under the VCX umbrella, the result is clearly marked as "provisional".

Tenet 2. (VCX shall remain 100% objective): The complete process on how the score is created from measurements is based on objective analysis of the device under test, followed by a fixed and unbiased processing of the numerical results. No human interaction or subjective scoring is involved when calculating the VCX score.

Tenet 3. (VCX shall remain open and transparent): The VCX score can be accessed by anyone and not restricted to device vendors or mobile operators. The VCX score is designed to reflect the user experience with a mobile phone camera to make it much easier for end-users to decide on a new device. The VCX score is published on the website www.camtest.eu. A whitepaper details the entire testing and measurement procedure, which is open to critique and scrutiny by the imaging community at large. High level weighting criteria is published. To avoid any cheating of the test results by manufacturers the detailed rating is only visible to members who have signed a code of honor in which they bind themselves to caring about the image quality in general and refrain from trying to manipulate devices to get better scores.

Tenet 4. (VCX shall employ/use an independent imaging lab for testing): VCX as a quality improvement process has been adopted by various entities in the mobile imaging industry, but the final results that get published are obtained from an independent trusted lab that gets certified by the VCX-Forum e.V. Independent imaging labs are welcome to join the VCX-Forum and become a trusted lab.

Tenet 5. (VCX shall seek continuous improvement): VCX has been developed over several years with close cooperation between Vodafone and Image Engineering. Continuous input from the Industry has been taken into account for improvement. Several vendors from the mobile device and chipset industry have contributed positively to its improvement and this cycle of feedback from customers shall continue and VCX-Forum members will decide on the path forward.

The measurement

The final result of the applied test procedure is a single VCX score that shall reflect the user experience regarding the image quality and the performance of a camera in a mobile phone. To generate the score, the image quality and performance is measured under different, controlled light conditions.

The VCX score is generated based on 100% objective data. The objective data is the result of well-defined and transparent test procedures following international standards where possible. Objective data means that at no point in the analysis process a judgment is made by a human observer on the performance of an individual device. The entire analysis is only based on the captured images and the analysis algorithms applied to these images. Based on a fixed algorithm, the score is calculated using the numerical results.

The only time where subjective judgments come into play is when a new version of VCX is created and a team of experts from the VCX-Forum members needs to define the calculation of the score from the measurement values. It would be nice to make this step also objective by measuring JNDs (just noticeable difference) as described in [1]. This approach has been chosen for the IEEE CPIQ initiative and is one of the reasons the initiative still hasn't gotten to a state of a usable standard after 11 years of work. For VCX it has been too time consuming and costly in the past but maybe with the current members a possibility arises to follow the JND path in the future.

The image quality is evaluated for five different use cases (see test conditions in section covering the most important aspects like:

1. Spatial Resolution – What level of details can I see?
2. Texture loss – How does the device reproduce low contrast, fine details?
3. Noise – How much disturbing noise do I see?
4. Dynamic range – What is the maximum contrast in a scene the device can reproduce?
5. Color Reproduction – Are there any issues in the color processing?

Capture conditions

Since cameras are used in different capture and lighting conditions the rating system needs to cover the typical ones and weight them in the same way as they occur. VCX currently uses the following conditions:

Bright – This condition is used as the *Reference.* It is performed with a brightness of 1000lux while the device is mounted on a tripod.

Mid – As we do not control the exposure manually, we reduce the light intensity by *2EV*, which results in an illumination level of 250lux. This light condition reflects a normal (office or kitchen) indoor light situation without direct daylight.

Low – A low light situation is the most challenging situation for a camera. In this case, we reduce the illumination by 4EV compared to the reference (bright), which results in an illumination level of 63lux.

Flash – If a situation is too dark, mobile phones mainly use LEDs to illuminate the scene. As a phone is rarely used in cases where there is absolutely no light, the flash is activated for this measurement while the scene is still illuminated with 63lux (Low).

Zoom – To zoom onto smaller objects is a very common use case for mobile phone cameras. In order to evaluate the image quality of a zoomed image, we capture an image of the TE42 with 4x zoom at 1000lux. In case the device provides an optical zoom, we use the optical zoom first and add digital zoom if needed, to achieve a 4x zoom. For devices that only offer digital zoom (the standard case of the majority of today's mobile phones), we use a 4x digital zoom.

The capture conditions are subject to change in the next upcoming version of VCX because 63 lux are not low enough to differentiate the performance of today's cell phone cameras. In addition the typical spectral distribution of the illumination at the different light levels tends to be warmer for low light levels than for bright ones, which needs to be reflected as well.

Test of the selfie cameras and video performance need to be added in the future as well.

Viewing conditions

Certain aspects of image quality like resolution and noise are more important when images are reproduced in a large size or images are cropped before viewing. Therefore the score also needs to take these into account.

Three major conditions have been identified and are used for VCX:

VC 1 – 100% view – This is the worst case scenario, as the user can see every detail (every pixel). We assume a viewing distance of 0.5 m and a 100% view on a 96ppi display. This means that each pixel of the image matches one pixel on the display. The more pixels in the image, the larger it is displayed.

VC 2 – Small Print / Smart Phone Display – The complete image is scaled to a height of 10cm, the viewing distance is the natural viewing distance. The natural viewing distance is defined as the diagonal of the image with a minimum of 25cm. So in this case, the viewing distance equals 25cm.

VC 3 – Large Print / PC or TV Display – The complete image is scaled to a height of 40cm. The viewing distance equals the diagonal of the image, so it depends slightly on the aspect ratio.

Metrics

To minimize the time and cost for the measurement the VCX team has tried to determine several measurements from a multipurpose chart similar to the one described in ISO 19093, the standard for low light performance measurements.

From images of this test chart the following measurements can be derived:

1. Resolution (s-SFR) in the center and the corners according to ISO 12233 [5] (limiting resolution at the 10% modulation threshold).
2. Acutance measurement for the center and the corners. This is the area under the MTF (Modulation Transfer Function) curve weighted by the CSF (Contrast sensitivity function) of the human eye for the three viewing conditions.
3. Sharpness (e-SFR) as the frequency where the SFR of a low contrast edge reaches the 50% modulation threshold. The e-SFR is determined based on ISO 12233.
4. Over-sharpening derived from the overshoot and undershoot of the e-SFR.
5. Texture loss based on ISO 19567-2 [10] meaning the loss of low contrast fine detail because of noise reduction algorithms.
6. Artifacts introduced into the image as the difference between the texture loss and the power spectrum derived for a dead leaves pattern in the image.
7. Chroma loss as the loss of color due to noise reduction in the images.
8. Color reproduction quality in Delta E for Color Checker SG type colors (with a low weighting because a cell phone camera is made to produce pleasing colors not to accurately reproduce colors).
9. Accurate white balance for daylight situations.
10. Visual noise according to ISO 15739 [4].
11. Dynamic range according to ISO 15739.
12. Luminance and Color Shading according to ISO 17957 [8].
13. Distortion according to ISO 17850 [6].

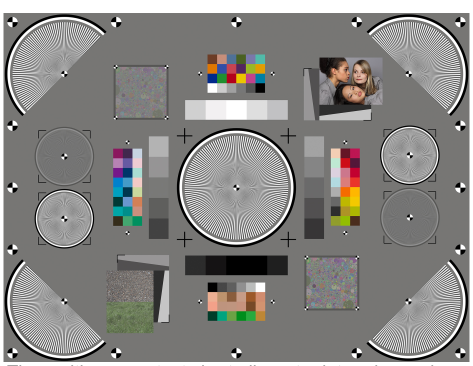

Figure 2: The multipurpose test chart allows to determine various aspects.

Additional images need to be captured to determine:

1. Timing values (frame rate, shooting time lag, shutter release time lag, Startup time) according to ISO 15781.
2. AF failure rate.
3. Image Stabilization according to ISO 20954 at 800 lux and 40 lux.

Calculation of the VCX score

The VCX score is calculated based on objective, numerical results. It does not contain any visual assessment or other subjective components.

The only subjective component is the weighting, so the decision which metric is more important for the overall performance compared to others. But this weighting has been accurately determined by a group of experts and it is identical for every device, so the comparison between devices is fixed and not influenced by individual opinions.

The total score range is between 0 and 100. The range is designed in a way, that a value of 100 means, that the device meets the best possible result in every metric that is achievable with today's camera technology. So it can happen that in the future the value of 100 is exceeded or that the range has to be modified.

The VCX score is the sum of the image quality score (0…70) and the handling score (0…30).

The image quality score is generated from the different test conditions.

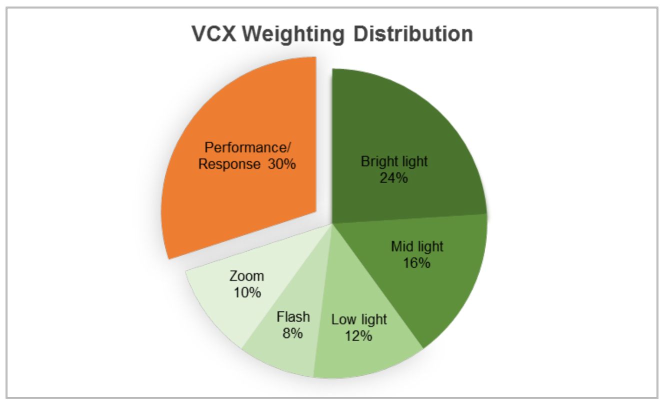

Figure 3: Weighting of the different capture conditions.

For each of the used metrics, a single score is calculated via bespoke algorithms/formulae developed specifically for VCX by Vodafone derived from use-case studies. The total score is a weighted sum of all scores.

The weighting of the different aspects of image quality is the result of an internal case study by Vodafone on how mobile phones are used as well as a study on millions of images presented at the Electronic Imaging Conference 2009 [2].

The transformation of metrics into scores is performed under the definition of a theoretical worst and theoretical best value. The scaling is performed in different ways between the extreme points, depending on the metric itself. For some metrics, the correlation between "metric" and "influence in image quality" is linear, so the score is a linear function of the metric. This would be in the case of a simple "the higher the better" or "the lower the better" assumption.

For others, this assumption is not true. Some metrics require a different approach to the one previously mentioned, because it would not reflect the perceived quality. Sharpening is a good example for this behavior. No sharpening is not beneficial for the image quality, as an image would appear flat. But at the same time, a very high sharpening very quickly results in an artificial and unpleasant look of the image. So there is a “sweet spot” and below or above this leads to a reduction in the score.

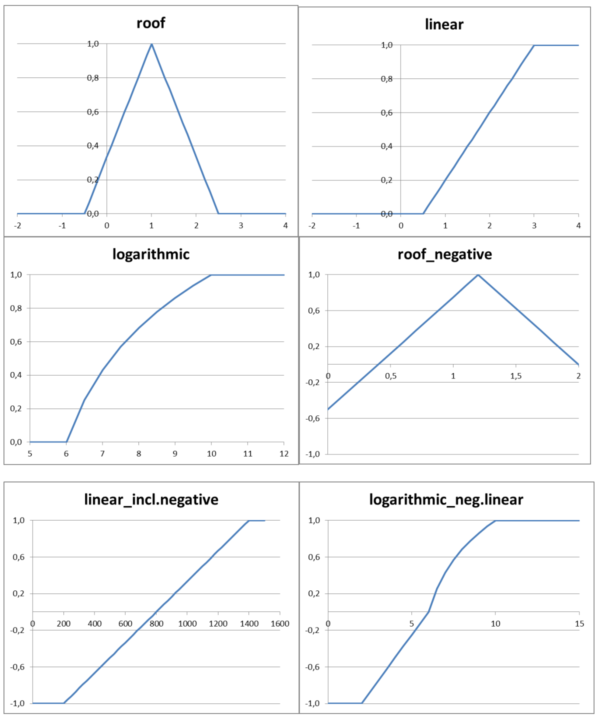

Figure 4: Examples for metric to score functions

The score generation is checked and may be updated with new test versions based on the technological developments in the industry.

Lower gating criteria (LGC) and higher gating criteria (HGC) are defined for the measured parameters during VCX evaluation.

Lower gating criteria defines the minimum acceptable value for that particular parameter. If a device doesn’t top the LGC, the score is omitted from final result. For example, if the chrominance error or visual noise is too high and is deemed unacceptable, the score is omitted from the final result (sum). By extension this means that two devices that have been measured below the LGC despite having disparate lab results, will end up adding nothing to the final score. In case of resolution related parameters, score deduction formulae are applied when the values are below customer acceptance, because the recognition of important parts of the images is key to photography. This ensures that devices with an unacceptably low resolution will not score too high, even though other parameters like color reproduction or visual noise are very good. This is most likely to happen under zoom condition.

Higher gating criteria defines the quality/technological limit beyond which there is no perceptible quality difference. Hence two devices with disparate measured values over HGC will end up having the same score for that particular parameter. For example visual noise or dynamic range.

Overview of numeric results

Overview of all image quality values per lighting condition

Group	UID	Description
Dynamic Range	OECF-DR	Dynamic Range (DR)
Visual Noise	VN-Display	Visual Noise 1 (VC1) mean
	VN-Max-Display	Visual Noise 1 (VC1) max
	VN2	Visual Noise 2 (VC2) mean
	VN2-Max	Visual Noise 2 (VC2) max
Resolution	Res-EPC_Overall	Effective Pixel Count (EPC) overall
	Res-Contrast_Overall	s-SFR - Acutance overall
Texture Loss	TL_DL_HC_MTF10	Texture Loss MTF10 high contrast
	TL_DL_HC_vMTF1	Texture Loss Acutance high contrast
	TL_DL_LC_MTF10	Texture Loss MTF10 low contrast
	TL_DL_LC_vMTF1	Texture Loss Acutance low contrast
	TL_DL_Artifacts_HC	Artifacts high contrast
	TL_DL_Artifacts_LC	Artifacts low contrast
	TL_DL_C-Star_HC	Chrominance (C*) high contrast
	TL_DL_C-Star_LC	Chrominance (C*) low contrast
Sharpening	Edge_Data_HC_ OverShoot_A2	Overshoot 2 (OS2) high contrast
	Edge_Data_HC_ UnderShoot_A2	Undershoot 2 (US2) high contrast
	Edge_Data_LC_ OverShoot_A2	Overshoot 2 (OS2) low contrast
	Edge_Data_LC_ UnderShoot_A2	Undershoot 2 (US2) low contrast
Color	DE-Skin	ΔE - Color Error (skin tones)
	DE-Luminance	ΔL - Luminance Error (all)
	DE-Chrominance	ΔC - Chrominance Error (all)
	DE-Colourtone	ΔH - Hue Error (all)
White balance	Shading-WB	White Balance
Shading	Shading-IS_Fstop	Intensity Shading
	Shading-CS_Deab	Color Shading [ΔE_ab)
Distortion	Distortion-TV	TV-Distortion

Overview of all performance results

Group	UID	Description
Frame Rate	FrameRate-10pics	Framerate for 10 Pictures
	FrameRate-10pics-CL	Compression Loss - Framerate
Response	ShutterLag	Shutter Release Time Lag
	ResponceTime-StartUp	Startup-Time
	Shooting_Time_Lag	Shooting Time Lag
AF performance	AF_Failure_rate_	AF-Failure Rate (AFR)
Image Stabilization	STEVE_ON-VN	STEVE on VN1
	STEVE_ON-DeltaVN	∆ STEVE on VN1-STEVE off VN1
	STEVE_ON-Contrast	STEVE on acutance
	STEVE_ON-DeltaContrast	∆ STEVE on acutance/STEVE off acutance
	STEVE_ON-EdgeWidth	STEVE on Edge Width
	STEVE_ON-DeltaEdgeWidth	∆ STEVE on width/STEVE off width

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[5] ISO 12233 Photography - Electronic still-picture cameras - Resolution measurements

[6] ISO 17850 Photography - Digital camera - Geometric distortion (GD) measurements

[7] [ISO 19084 Photography - Digital cameras - Chromatic displacement

[8] ISO 17957 Photography - Digital cameras - Shading measurements

[9] ISO 18844 Photography — Digital cameras — Image flare measurement

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Author Biography

Dietmar Wueller studied photographic technology at the Cologne University of applied sciences. He is the founder of Image Engineering, an independent test lab that tests cameras for several photographic and computer magazines as well as for manufacturers. Over the past 20 years the company has also developed to one of the world's leading suppliers of test equipment. Dietmar Wueller is the German chair of the DIN standardization committee for photographic equipment and also active in ISO, the IEEE CPIQ (Cellphone Image Quality) group, and other standardization activities.