



Sofica Benchmark Report

Technical Description



Summary

Sofica Benchmark Report enables a product comparison by camera performance. The Camera performance is determined by measuring the speed and the quality of the camera. The camera speed is measured using several image capturing use cases like time to take the first picture and time to take several shots in a row. On the video recording side, audio-video synchronization is measured. In case of image quality, noise, color accuracy and sharpness of the captured image are measured. Though Sofica Benchmark Report concentrates on the most obvious use cases, more measurements can be easily added and executed.

This document describes the technical details of the Sofica Benchmark Report product including the measurement environment, measurement sequences and Sofica Benchmark Report deliverables.

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Terms and Abbreviations

API	Application Programming Interface
Arduino	Open-source single-board microcontroller platform
AV	Audio/Video
CCT	Correlated Color Temperature
CIE	<i>Comission Internationale de l'Eclairage</i> (International Commission on Illumination)
CIE76,CIE94, CIEDE2000	Three different methods by CIE to calculate color difference
CMC	Color difference calculation method by the Colour Measurement Committee of the Society of Dyers and Colourists (1984)
Dalvik	Virtual machine process in Google's Android operating system.
DUT	Device Under Test (i.e. target hardware)
iOS	Operating system of IPHones
ISO	International Organization for Standardization
Lab	Color space of luminance and two color dimensions
LCD	Liquid Crystal Display
LED	Light Emitting Diode
MTF	Modulation transfer function
OECF	Opto Electronic Conversion Function
RGB	Reg Green Blue color mode
RMS	Root Mean Square
SDK	Software Development Kit
SNR	Signal to Noise Ratio
SoMA	Sofica Multimedia Test Automation Solution. The solution includes physical test environment building blocks, test automation enabler software and test cases and services used for automatic image and video verification.

Table 1: Terms and Abbreviations

1 Benchmarking Environment

Two different environments are used when the camera benchmarking is measured. Audio/video synchronization measurements are done in the SoMA environment whereas other speed related measurements and quality measurements are done in imaging laboratory.

1.1 SoMA

The audio/video synchronization measurements of Sofica Benchmark Report are executed in the SoMA test environment (Figure 1). The environment ensures stable and comparable measurement environment between the measurements. The environment contains a test box with electrical wirings, a high resolution LCD display, robot arm, loudspeakers, light box with test charts and microcontroller based AV synchronization measurement devices.



Figure 1a: Test box



Figure 1b: Text box content

SoMA environment offers a varied distance between the camera and captured object. The distance can be adjusted between 25-65 centimeters (10-25 inches).

Audio/video synchronization measurements are done in static conditions. The corresponding illumination value is **200 luxes**. The source of the illumination is Cold Cathode Fluorescent Lamps of the LCD display.

The Audio/video synchronization measurement is based on SoMA performance testing, which provides a great mass of different speed tests. Several combinations of performance tests can be selected to the Sofica Benchmarking Report. See also chapter 4, SoMA Extensions.

1.2 Imaging Laboratory

A separate imaging laboratory is used to measure camera speed and image quality. The dimensions of the laboratory environment can be found from Figure 2. The imaging laboratory supports aspect ratios 4:3 and 16:9.

All measurements are done in normal office temperature: 23 degrees Celsius, 77 degrees Fahrenheit.

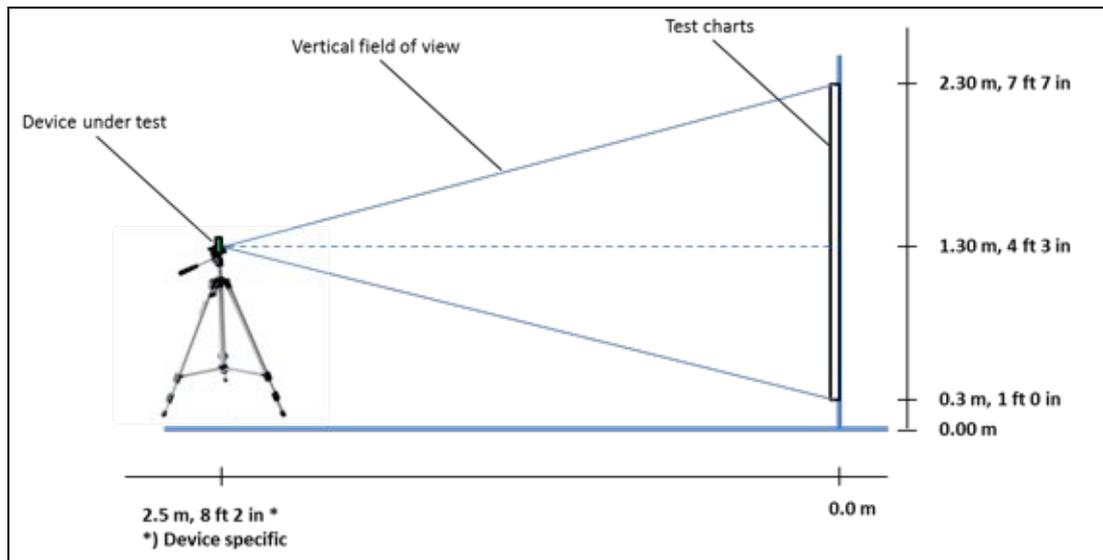


Figure 2: Imaging laboratory dimensions

1.2.1 Illumination

Kino Flo light system is used in imaging laboratory. The system contains four Kino Flo IMAGE 45 DMX lights [1]. The lights include Kino-Flo True Match tubes which color temperature is 5500 K.

Sofica Benchmark Report is measured using one illumination environment; 1000 lux. However, different illumination environments can be also used to measure for example low light speed and quality. Even illumination is ensured by measurements using Konica Minolta CL- 200A [2]. The illumination difference is less than 10% between the test charts.

1.2.2 Scene

The background of the scene is 18% neutral matt grey and test charts are mounted to the scene. The scene contains following test charts:

- 20 grey patches to calculate OECF curve and ISO noise
- Macbeth color chart to color accuracy measurements
- Slanted edge charts in the middle and each corner to sharpness measurement
 - o 5% angle is used
 - o 4:1 contrast is used
- Dead leaves chart to sharpness measurement and to detect denoising and sharpening defects

Sofica Benchmark Report detects every test chart from the captured images automatically and measures corresponding image quality values.

Both environments are connected to the verification server, database and user interface as Figure 3 shows. The speed and quality verifications are done inside the verification server and measurement results are stored to the database.

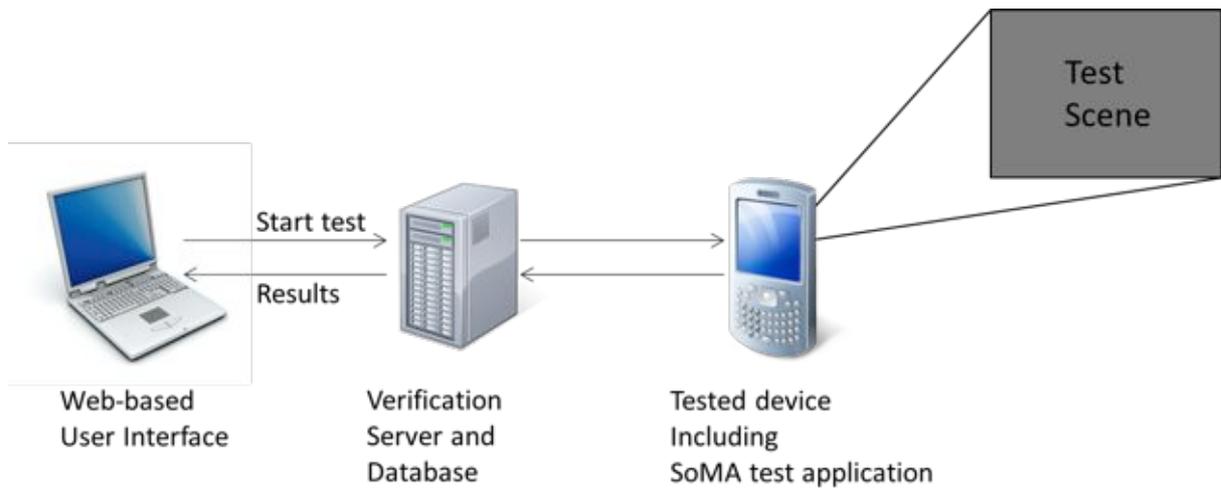


Figure 3: Sofica Benchmark Report environment

2 Sofica Benchmark Report Measurements

2.1 Speed Measurements

The speed measurements contain four still image measurements and one video measurement. The still image measurements are shown in Figure 4.

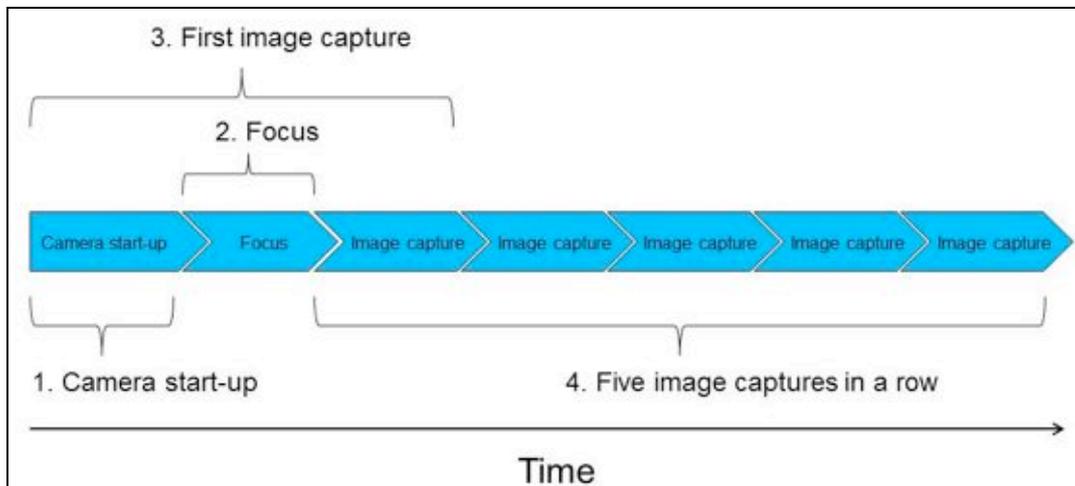


Figure 4: Still image speed measurements

2.1.1 First Image Capture

First Image Capture measurement measures the total time taken to capture one picture when camera has to start before capturing. The total time includes camera start up time, focus time and capture and image processing time. These values are also informed separately by Sofica Benchmark Report. The use case represents the time which elapses when the end user starts the camera and presses the shutter button to the moment when picture is available for viewing.

2.1.2 Five Image Captures in a Row

Five Image Captures in a Row measurement captures five images in a row. In this case focus is set before capturing the first image and the time taken to focus is not calculated in the measurements. Either the camera start up time is not included in the measurement.

2.1.3 Audio/Video Synchronization

Audio/Video synchronization measurement measures how well the recorded video has audio and video correctly synchronized.

Synchronization is calculated from flashes and beeps produced by external Arduino hardware inside the test box. The Arduino board is connected to a LED and a speaker. The audio beeps and LED-flashes are played sequentially and simultaneously.

Synchronization is measured with two different scenarios. In the first use case, the measurement is executed in a very static environment where the recorded video contains very few object changes from frame to frame. If variable frame rate is used in the video recording, the measurement may reveal remarkable delays between audio and video streams. In the second case the objects are changing constantly in the recorded video which creates more stress for the video encoder.

2.2 Quality Measurements

Quality measurements of Sofica Benchmark Report concentrates the main quality attributes of the still image capturing: color accuracy, noise and sharpness of the captured image. Each quality attribute defines two quality values which are used in Sofica Score calculations. The measurements are using standard charts and algorithms. These three measurements give a good overview of the camera quality.

2.2.1 Color Accuracy

Color Accuracy measurement calculates the color reproduction error of the camera. The measurement calculates also white balance, luminance and exposure errors and density response of the camera as these affects to the reproduction of colors. Standard Macbeth color chart as the reference image. The measurement is done according to the CIE organization [3].

CIEDE2000 ΔE_{00} value and mean saturation error of grey patches are selected to the Sofica Score calculation. The values are mean values of eight different images. The saturation error of the grey patches should be as near zero as possible and the values are scaled to values 0-1.

The detailed results contain ΔE_{00} and ΔC_{00} (CIEDE2000) values reported as average and maximum values. The exposure and saturation errors are calculated from Macbeth grey patches and reported in the detailed results, too.

2.2.2 Noise

Noise measurement is used to measure the noise generated by camera. There are two different noise measurements: ISO SNR and visual noise. The ISO SNR measurement captures minimum eight images and noise is calculated according to ISO15739:2003 [4]. The visual noise measurement uses same images as ISO SNR and the calculations are done according to the ISO15739:2013 [11].

ISO SNR

Detailed noise measurement results contain fixed pattern, temporal and total noise for each color channel according to ISO15739:2003 [4] and corresponding SNR values. The temporal noise is random noise varying between images and fixed pattern noise is temporally (in same imaging conditions) consistent noise. The total noise is sum of temporal and fixed pattern noise. Also average noise values of all grey patches are reported as well as the dynamic range.

ISO SNR value is used to the Sofica Score calculation. The value is mean value of eight different images.

Visual Noise

Visual noise measures the noise of the captured image a way which correlates to the visual appearance of noise in images. The measurements are done according to the Annex B of the ISO15739:2013 [11].

The visual noise values are calculated from eight images and the mean values of each gray patch (20) are calculated.

Visual Noise RMS value of gray patches is used to the Sofica Score calculation.

The detailed result of visual noise includes visual noise value of each gray patch (20) of the Sofica test scene as well as average sRGB pixel value and lightness (L^*) of each gray patch.

2.2.3 Sharpness

Sharpness measurement is used to verify image sharpness and texture reproduction. The measurement does basic quality verification (brightness, contrast, white balance) for image before verifying actual sharpness.

The sharpness calculations are based on slanted edge measurements using 4:1 contrast slanted edge charts. The measurements and calculations are based on ISO 12233 standard [5].

The texture reproduction measurement detects denoising and sharpening defects which are not so visible in the slanted edge measurements. Nowadays, there is lot of discussion about different methods of the texture reproduction measurements. The dead leaves method is one of the most acknowledged one. The texture reproduction measurement and calculation is done according to several papers [6], [7], [8] and [9]. The mean MTF of four color channels are calculated from the dead leaves chart: $\overline{MTF}_{\text{dead_leaves}}$. Moreover, mean value from eight different images is calculated: $\overline{MTF}_{\text{dead_leaves_8}}$.

Due to several test charts and measurements of every color channel, the MTF measurements are quite complicated. The final MTF curves are calculated using following steps:

1. MTFs of each (4) slanted edges are calculated for every slanted edge charts (5) using four different color channels (red, green, blue, luminance) are measured and calculated. Totally 80 MTFs are measured.
2. Mean value of horizontal edges (8) of corner located charts and each color channels are calculated: $\overline{MTF}_{\text{horizontal_corners}}$
3. Mean value of vertical edges (8) of corner located charts and each color channels are calculated: $\overline{MTF}_{\text{vertical_corners}}$
4. Mean value of horizontal edges (2) of center chart and each color channels are calculated: $\overline{MTF}_{\text{horizontal_center}}$
5. Mean value of vertical edges (2) of center chart and each color channels are calculated: $\overline{MTF}_{\text{vertical_center}}$
6. Mean value of slanted edge is calculated from steps 2-5: $\overline{MTF}_{\text{slanted_edge}}$. This kind of mean calculation highlights the center resolution.
7. Mean value from eight different images is calculated: $\overline{MTF}_{\text{slanted_edge_8}}$

MTF50_Peak values of the slanted edge and dead leaves measurements are used to the Sofica Score calculation. In case of dead leaves measurement, the MTF values are noise corrected, i.e. measured noise component is reduced from the MTF-values.

Detailed sharpness measurement results contain MTF peak, MTF50, MTF50_Peak, MTF20 and MTF20_Peak values of horizontal and vertical directions of center and corners. Also mean MTF values of center patch each corner is separately described. All values are calculated from luminance channel.

Detailed results of the texture reproduction include MTF peak, MTF50, MTF50_Peak, MTF20 and MTF20_Peak values of each color channel (red, green, blue and luminance).

The sharpness is measured by using unit LP/PH (Line Pairs/Picture Height). Using this unit, number of pixels of the sensor is also taken into account and different sensor sizes are compared fairly.

2.3 How Measurements Are Executed

Sofica Benchmark Report measures the speed and the quality of the camera features using the software interface provided by the corresponding operating system. The software interface closest the user interface is used and therefore the benchmark measurements are done straight below the application layer of the camera software stack. This is the same software layer, which the camera applications of each operating system are using as Figure 5 shows. Moreover, when this interface is used, the performance variations of different user applications are eliminated.

Measurements are done using the public APIs and official SDKs of different mobile operating systems. Official SDK are used and measurement points are selected so that they are comparable on different devices and operating systems.

The following list shows the used APIs of currently supported operating systems:

- Android: Java Camera API (Dalvik)
- Windows Phone 7: Windows Phone Managed Camera API
- Windows Phone 8: Windows Phone Runtime Camera API
- iOS: AV Foundation

During the measurements, the default camera settings are used to reflect normal end user behavior.

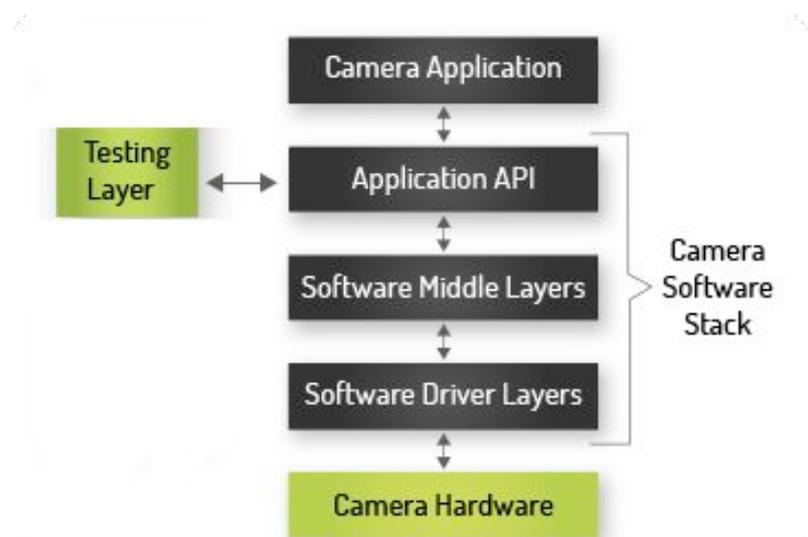


Figure 5: Camera Software Layers and Sofica Benchmark Report

2.3.1 Measurement Execution Example

The following list and Figure 6 defines the steps which are executed when focus measurement is executed on a phone using Android operating system.

1. A phone which includes Sofica's measurement application is inserted to the test box.
2. The phone mounting is calibrated using corresponding measurement.
3. Measurement is started from the user interface.
4. The measurement application starts the performance measurement
 - a. *android.hardware.Camera* API is opened
 - b. Camera parameters are set to default values

- c. Camera preview is started
 - d. *autoFocus* is called and the timing is started
 - e. When *AutoFocusCallback* is received the timing is stopped and elapsed time is calculated.
5. The measurement application sends the results to the database.
 6. The benchmarking result is calculated by the reporting server.

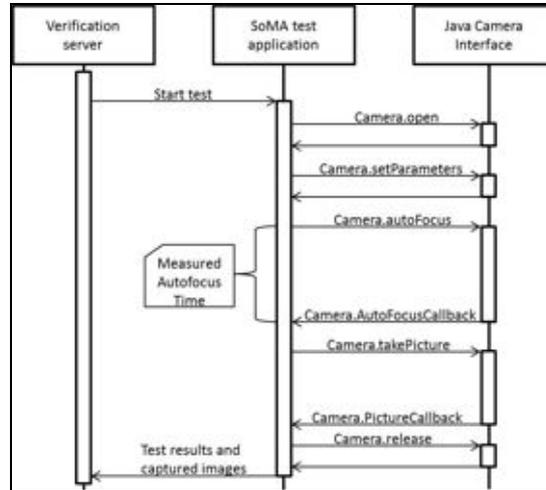


Figure 6: Simplified focus measurement flow in the tested device

2.4 How Results Are Calculated

Each speed measurement is executed at least five times and means are calculated to the Sofica Benchmarking Report. The outliers are detected from the measurement values and if they are judged as result of erroneous camera functionality, they are dropped out. The detailed information of the outliers is described in the report.

In case of quality measurements, each measurement is executed minimum eight times and means are calculated to the Sofica Benchmarking Report. The outliers are detected and informed as in the speed measurements.

2.4.1 Sofica Score

The final rank between different built-in cameras is done using Sofica Score. The score includes the measurements of speed and quality measurements. The speed and quality scores are calculated separately and finally combined to Sofica Score value using geometric mean as described in formula [1]

$$\text{Sofica Score} = \sqrt{\text{Speed Score} \times \text{Quality Score}} \quad [1]$$

Speed Score

Speed score is a weighted sum of the speed measurements. It is scaled using scaling constant (3 000 000) according to formula [2] from the measurements defined chapter 2.1.

$$\text{SpeedScore} = \frac{\text{SoficaSpeedScalingConstant}}{\text{FirstImageCaptureTime} + \frac{\text{FiveImageCaptureTime}}{5} + \text{AVSync}} \quad [2]$$

Audio/Video Synchronization values are calculated differently depending on the delay direction. If the value is negative, meaning that the image information is delayed towards

audio information. This delay is more annoying to human than opposite one and therefore the audio/video synchronization values are weighted according to formula [3].

$$AVSync = \begin{cases} \text{if } AVSyncStressed > 0, & AVSyncStressed \times 10 \\ \text{if } AVSyncStressed \leq 0, & |AVSyncStressed| \times 20 \end{cases} \quad [3]$$

Quality Score

Quality score is calculated using geometric mean of the quality value according formula [4]. It is notable, that equation [4] does not use any weight components between quality metrics but each measured quality metric is used as such. The only exception is saturation error which value is summarized with 0.1 to decrease its too big influence to the total score.

The quality score is squared. Otherwise, the variance of the quality score is much smaller than speed score and this leads to dominance of the speed score when Sofica Score is calculated. Moreover, Quality Score is multiplied with 4 to equalize the score range to the same level than speed score range.

$$\text{Quality Score} = \left(\sqrt[6]{MTF50P_{\text{edge}} * MTF50P_{\text{deadLeaves}} * SNR * \frac{1}{\Delta E_{00}} * \frac{1}{(0.1 + \text{satErr})} * \frac{1}{VN}} \right)^2 * 4 \quad [4]$$

2.4.2 Sofica Score Evaluation

It is widely known a single score can be very misleading and using appropriate equations and weights the result score can be manipulated very efficiently.

Speed and quality scores are weighted so that the data ranges of the scores are as equal as possible. The equations ensure also that each speed and quality variables have as same influence as possible to the final Sofica Score. The evaluation results can be seen from Table 2.

Variable	Variable's influence to median Sofica score when variable's minimum and maximum values are used (%)
Speed score	95
Quality score	104
First image capture	44
Five image capture	43
A/V Synchronization	25
Edge MTF	15
Dead leaves MTF	18
ΔE_{00}	17
Saturation error	15
SNR	14
Visual Noise (VN)	18

Table 2: Sofica Score evaluation results

3 Results and Reports

3.1 Report Delivery

The report delivery will contain following documents and data:

- Microsoft Excel document which contains all speed and quality measurement values including possible outlier values.
- Packed file, which contains all captured images in JPEG format.
- This document, which defines the measurement environment, measurement sequences and score calculations.
- Report
- Access to the Sofica Benchmark Report system, where all measurement results are available.

3.2 Report

The report [10] summarizes the measurement values according to the Sofica Score, Speed score and quality score. The report includes also detailed measurement values of each measurement.

Depending on the customer's needs, the report may contain for example following comparison between devices:

- Sofica Scores of selected devices in the market and corresponding score of target device
- The target device towards the average of the devices in the market
- The target device towards the top five devices in the market

4 SoMA Extensions

Sofica Benchmark Report includes the most obvious camera use cases. However, the report is based on the speed and quality measurements of the SoMA product. SoMA product contains significantly larger test content. SoMA tests and different combinations of these tests can be also used when products are benchmarked.

References

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