User Guide

Related standard	**IEC 62977-3-5, clause 6.6, 6.7, Annex B**
Subject	**Colour gamut calculation and visualization application for additive and non-additive displays**
Contents	This application calculates the absolute and intersecting CIE 1976 *L*a*b** (CIELAB) colour gamut and CIE 1931 *xy* chromaticity gamut area, either for a single output device or relative to another output device, synthetic measurement, or a built-in reference colour space. It reads measurement data from text files formatted in accordance with ISO 28178, applies the linear Bradford chromatic adaptation transform for D50, and plots gamut rings and graphs in the CIELAB, CIE 1931 *xy* or *xyY* diagrams. The results can be exported in portable network graphics (PNG), tag imaged file (TIFF), encapsulated Postscript® (EPS), portable document format (PDF), enhanced metafile (EMF), and joint picture expert group (JPEG) file formats, and thereafter imported into a variety of documents. The application is available for Microsoft® Windows® and Apple MacOS®. The following files are included in the archive: 1. GamutRingsViewer_Installer_0.4.7_r8.exe (Windows) 2. GamutRingsViewer_Installer_0.4.7_r8_ARM.app (MacOS) 3. GamutRingsViewer_Installer_0.4.7_r8_Intel.app (MacOS) 4. GamutRingsViewer_UserGuide_0.4.7_r8.pdf (this file) 5. sample_measurement_data.txt 6. readme.txt (list of changes from 0.4.7r7 to 0.4.7r8).
Installation and launch (Windows)	Double-click on the file “GamutRingsViewer_installer_0.4.7r8.exe”. If the required MATLAB® runtime is not yet installed, the relevant version will be automatically installed (this could take some time depending on the network connection). Accept the end user license agreements (EULA) for both the runtime and the application. The runtime and the application are thereafter installed and launched similarly to other applications. Installation may require administrator permissions. From the Windows menu, search for and select “GamutRingsViewer” or double-click on its icon on the desktop. Note that launching the application for the first time could take several tens of seconds.
Uninstallation	From the Windows menu, navigate to Settings/Apps & features and

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<tr><td>(Windows)</td><td>search for “GamutRingsViewer”. Select it and click the Uninstall button. If the MATLAB® runtime is not needed for other applications, uninstall it similarly by searching for “MATLAB”.</td></tr>
<tr><td>Installation and launch (MacOS)</td><td>The MacOS version of the app is unsigned, so the following modifications to the system are necessary. Admin rights are required to unlock some settings and the steps may vary with MacOS version. Furthermore, the installer apps may not execute if they have been stored on a non-MacOS system. In that case, perform also step 4 below.
1. Open the Terminal in Utilities.
2. Execute the following command followed by the user password:
<code>sudo spctl --master-disable</code>
3. In the Apple menu, go to System Settings/Privacy & Security, scroll down to Security, and check the button “Allow applications downloaded from Anywhere.”
4. From the Terminal, navigate to the directory of the installer and execute the following command:

<code>xattr -c ./GamutRingsViewer_installer_0.4.7r8_XXX.app</code>
where XXX is the architecture of your computer (ARM or Intel). If the installer still does not run, execute the following additional commands in the terminal:
<code>cd GamutRingsViewer_installer_0.4.7r8_XXX.app</code>
<code>cd Contents/MacOS</code>
<code>sudo chmod +x setup</code>

Installation procedure is as follows:
1. Double-click the file “GamutRingsViewer_installer_0.4.7r8_XXX.app”.
2. Accept the EULA.
3. Enter your administrator credentials in the dialog box “MATLAB wants to make changes to the system” and proceed with the installation.
4. Install Java Runtime if requested to do so.
5. From the “Go” menu in Finder, navigate to the Applications folder, open the GamuRingsViewer/application folder, and double-click GamutRingsViewer.
6. From the terminal, execute the following command:
<code>sudo spctl --master-enable</code>

Note that, depending on the MacOS version, launching the application for the first time could take several minutes and thereafter several tens of seconds. Note also that the ARM and Intel versions use different versions</td></tr>
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	of the MATLAB runtime, R2023b and R2022b, respectively
Known issues (MacOS)	1. The background of text boxes with the colour space selection buttons does not change when dark mode is selected. 2. The installers are not supported on MacOS versions prior to 10.16. 3. Installers do not run on Apple systems which do not support R2023b or R2022b. See this page for details. 4. The installer says that the environment variable DYLD_LIBRARY_PATH is undefined, but this warning can be ignored. 5. Splash screen does not appear.
Uninstallation (MacOS)	From the "Go" menu in Finder, navigate to the Applications folder and drag the folder "GamutRingsViewer" to the bin. If the MATLAB® runtime is not needed for other applications, uninstall it similarly by dragging folder "MATLAB" to the bin.
Reading input files	Select the input data file of the display under test (DUT) from the upper pop-up menu by clicking on "---Select File---" or, if no files have been selected, by clicking on the button to the left of the menu. Select and open the file from the file browser dialog. The selected data will then be plotted according to the selected space/diagram. Additional input files (including reference files) can be opened, and they then appear at the end of the menu. Switch between input files by selecting the appropriate file from the menu. If necessary, a second DUT (or synthetic measurement), reference data file, or a built-in reference gamut (also subject to D50 CAT) can be selected as a reference. This is done in the lower pop-up menu in the same way as in the upper pop-up menu. Remove previously opened files from the menus by selecting "---Clear---". Note that the input files must not contain any excess TAB characters. The default number of sampling points for the input file is 602 but it will work for any number of sampling points given by formula B.1 of IEC 62977-3-5. After reading the input file(s), the selected type of plot will be shown. The default plot is gamut rings for which the tristimulus values of the DUT white will also be reported. There is also a field where the DUT mode shall be entered. All measurements of the DUT shall be performed and reported in the same mode.
Graph selection	Toggle the buttons "Test" and "Ref" to turn on and off the respective plots. Hover the mouse above the buttons to display the absolute path to the selected file. Click on a button under "Space" to select the type of plot. To plot graphs for previously opened files, select them again from the data menus. To swap the test and reference plots, click on the leftmost button with two vertical arrows. The default graph mode is gamut rings

	intersection.
Graph layout	Adjust the size of the graph by dragging the window borders to the desired size or click the maximise button on the window bar. Note that the aspect ratio of the graphs does not change even if the aspect ratio of the window changes. Colours are rendered without colour management, so the appearance of the graph colours depends on the display in use, its settings, and host-side colour management, if any. The colours in the graphs are therefore only indicative of the DUT colour appearance. In the 3D graphs, the DUT and reference tessellations are rendered in black and constant grey, respectively. Click on the "Mode" button to toggle the polarity (white on black background or black on white background) of the plot. Hover the mouse above the graph to display the toolbar above the top right of the graph. Deselecting the plot makes the menu disappear. Click on any of the icons on the toolbar to enable its function (icon then turns light blue) and click again to select its function. The selected function can be turned off by clicking on the light blue icon again. Click on either of the magnification glass icons to turn on zooming ("+" for zoom in, and "-" for zoom out). Move the mouse to the region of interest and left click to zoom in/out. Right-click to zoom in the opposite direction. Click on the home icon to return to the initial magnification and view. Note that the numerical values of the areas/volumes might disappear in the CIE 1931 *xy* plot or are displayed outside the frame (Gamut Rings diagram) upon zooming. "Data Tips" (left-most icon in the toolbar) enables displaying of the numerical data corresponding to selected graph locations. Move the mouse to the desired region and left click to display the numerical data. Note that they are always labelled X, Y, and Z, which corresponds to the *a**, *b**, and *L** axes in the CIELAB plot. The numerical data can also be displayed in a separate window by right clicking on the graph and selecting "Window Inside Figure" from the "Display Style" menu item. The Data Tips can consecutively be posted on the plot by pressing Shift while left clicking, or by selecting "Create New Data Tip" from the pop-up menu.
CIE 1976 *L*a*b** **and CIE 1931 *xyY* plots**	The data can also be plotted in 3D and rotated by selecting the "Rotate 3D" icon. The default (initial) viewing direction is along the *L** (lightness) and *Y* (luminance) axis, respectively. The CIE 1931 *xyY* initial plot thereby coincides with the CIE 1931 *xy* chromaticity diagram. In both cases, the grey wire grid indicates the reference gamut boundary. Upon rotating, the viewing direction in terms of azimuthal and polar angles with respect to the *a**/*x* and *L**/*Y* axis, respectively, is displayed in the upper left corner of

	the window (A_z = 0, E_l = 90 is the initial viewing direction). To rotate the graph, click on the graph, hold down the left button, and move the mouse around. Click on the home icon to return to the initial view. This can also be accomplished by right-clicking and selecting "Restore View" from the pop-up menu. In the same menu there are also short-cuts for views perpendicular to each axis. If the graphics rendering of the system is slow, it might be beneficial to select "Plot Box Rotate" from the Rotate Options of the pop-up menu. However, the plot box is rendered in black and will therefore be invisible if dark mode is used. The "Stretch to fill axis" option can be used to resize the plot to the axes. Note that this is done continuously while changing the viewing direction, so it is recommended to switch to "Fixed Aspect Ratio Axes" after filling the axes.
CIE 1931 *xy* chromaticity diagram	This is the same plot as the *xyY* plot along the *Y* axis but without tessellations. The projection on the *xy* plane is done from the *XYZ* data corresponding to {*R, G, B, W*} values {255, 0, 0}, {0, 255, 0}, {0, 0, 255}, and {255, 255, 255} in the data file or the chromaticities of the reference colour space. The solid and dotted lines connect the chromaticity coordinates of the DUT and reference colour space, respectively. The test/reference absolute and intersection area ratios are also shown. For displays obeying colour additivity, these area ratios are proportional to the gamut (volume) ratios.
Gamut rings	This plot visualises the volume of the DUT colour gamut boundary in terms of coloured rings that encircle the origin in a 2D plot. The area of each ring is proportional to the volume of a slice in the CIELAB colour space. This slice is perpendicular to the L^* axis and bounded by two lightness levels, in this case L^* and L^* + 10 with L^* = 0, 10, 20,…, 90. The area between two contour lines bounding a ring is proportional to the sum of slice volumes from L^* and L^* + 10. Thus, the total area within the outermost contour line is proportional to the total DUT colour gamut (volume). The thickness of a ring at each hue angle θ represents the volume of that L^* slice between hue angles θ and $\theta + \Delta\theta$, where $\Delta\theta = 1°$. Likewise, the radius of each contour line at each hue angle represents the sum of slice segment volumes from $L^* = 0$ to the L^* of that contour between hue angles θ and $\theta + \Delta\theta$. Thus, the radius of the outermost contour is proportional to the DUT colour gamut volume between hue angles θ and $\theta + \Delta\theta$. The default plot mode for two gamuts (DUT and REF) is "intersection", which displays regions in colour for which there is gamut overlap between the DUT and the reference gamut. Non-overlapping regions are shown in grey. Select the plot mode from the pop-up menu by right-clicking on the

	plot. The arrows indicate the RGB hue angles of the DUT and are vectors between the origin and the rendered colour of each primary at maximum signal input. Note that the hue angles θ of CIELAB are preserved in the Gamut Ring diagram. The crossing points with the outermost reference Gamut Ring visualize the amount of hue error (green has the largest hue error for the example test display). The Gamut Ring diagram is also available in "outline" mode, where the total volume of the reference gamut is shown as a dotted outline. To enter this mode, right-click on the Gamut Ring graph and select "Outline" from the pop-up menu. Note that this plot only compares the absolute volumes of the two gamuts, so it is not possible to identify DUT colours that lie outside the reference gamut. Those out-of-gamut colours can instead be visualised by swapping DUT/REF or, better, in grey by using the intersection mode. Since the areas in the graph are proportional to the gamut volume, a direct visual comparison is possible. If several DUTs are to be compared, it is recommended to plot them all in the same size. In the "Data Tips" tool, the X and Y values correspond to the root sum square (RSS) variables and, respectively. The U and V values correspond to the coordinates of the spoke end points, but they do not have any colorimetric meaning. The absolute colour gamut volumes of the test and reference are displayed in CIELAB ΔE^3_{ab} unit. Also shown are the ratios of the DUT volume and intersection volume to the reference volume.
Exporting graphs	After adjusting the layout, the graph can be exported by clicking on the "Print" button (areas around the graph are cropped away). For bitmap image formats, the pixel count of the exported image depends on the size of the application window, graph layout, and the pixel count of the display in use. For example, a maximum window size on a 1920 × 1200 display produces a 1497 × 1431 and 1075 × 1448 image for the gamut rings and CIELAB plot, respectively, in their default orientations. Non-cropped images can be exported using the screen shot function of the operating system (Windows® key + PrintScrn for Windows®). Plots exported to EPS and PDF formats use scalable vector graphics and can be rasterized with any number of pixels.
Support	Questions regarding this application should be sent to gamutrings@gmail.com
Disclaimer	The IEC disclaims liability for any personal injury, property, or other damages of any nature whatsoever, whether special, indirect,

	consequential, or compensatory, directly or indirectly resulting from this software and the document upon which its methods are based, use of, or reliance upon.