QUALITY DRIVEN - AUTOMOTIVE DISPLAY TESTING

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Agenda

- Introducing Radiant Vision Systems
- Automotive Test Solutions
- Automotive Display Testing
  - Measurement Setup
  - Analysis Capabilities
- Mura Testing
- Black Mura Measurement Standard
Quantifying Human Visual Perception

Radiant Vision Systems’ imaging hardware and software replicate and quantify human perception of brightness, color and scatter.
A Konica Minolta Company
Automotive Applications - Overview

- Displays
- Instrument Panels
- Head-Up Displays
- Exterior Lighting
- Interior Lighting
- Materials & Finishes
Automotive Display Testing
The Automotive Challenge

High-quality perception of the display under harsh environmental conditions (over a long life-time)

- Temperatures -20°F to 185°F
- Read at nighttime and in sunlight

Dark-state displays are used to minimize distraction and preserve the dark-adaptation of the eye (nighttime)
“You See Everything on a Dark Display”

Display defects cause high-contrast artifacts that are easily spotted by the dark-adapted eye.
Common Display Tests

- **Brightness Offset**
- **Color Offset**
- **Non-Uniformity (Color & Brightness)**
- **Pixel & Line Defects**
- **Light Leakage**
- **Mura**
- **Image Sticking**
- **View Angle**
Automotive Display Test Setup

DVI/LVDS Converter & CAN interface

DUT
Secondary Display to PC

Colorimeter or Photometer

Dark Room

PC
TrueTest™ Software for OEMs & Suppliers

Developed with the needs of OEMs & Suppliers in mind

R&D / Engineering
- Many analysis tools
- Customization of tests
- Control of external devices
- Include home-brew analysis tools
- LabVIEW, Matlab, .NET API control

Production Testing
- 1-button control (Operator Mode)
- Fast testing
- Serial number tracking
- Report generation

Common language between OEMs & Suppliers
Standard Test Functions

Defect Testing
- Gradient
- Line Defects
- Particle Defects
- Pixel Defects

Mura Testing
- Color Edge Mura
- Color Mura
- Diagonal Pattern Mura
- Polarizer Deformation
- Spot Pattern Mura
- Automotive Black Mura

General Display Testing
- ANSI Brightness
- ANSI Color Uniformity
- Checkerboard Contrast
- Chromaticity
- Compare Points Of Interest
- Distortion
- Focus Uniformity
- Points Of Interest
- Uniformity

TrueMura Plug-In
For All Analysis Functions
Simple Positioning of the Device Under Test (DUT)

Automatic Detection of the Active Display Area

Automatic Correction of the Display Orientation

Automatic Image Crop Isolates the Active Display Area
For All Analysis Functions
Measuring Without Moiré Interference

Automated Moiré Removal

before Moiré removal

after Moiré removal
For All Analysis Functions

Compose a Test Sequence

1. Start Test for Serial#  
   - Test Luminance  
     - Pass / Fail
   - Test Uniformity  
     - Pass / Fail
   - Test for Black Mura  
     - Pass / Fail
   - Test for Dead, or Stuck Pixels  
     - Pass / Fail
   - Test Image Sticking  
     - Pass / Fail

Add Data to Report
Application Highlight
Mura Testing
Display Mura

Mura

- “Mura” is Japanese for “blemish”
- Local (gradual) increase/decrease in luminance – or “blob”
- Often a subtle gradient on-top of an unnoticeable large scale gradient
- Noticeability is highly subjective, therefore difficult to test reliably by humans
Common Causes of Mura

- Defect or stress in one or more layers
- Non-uniformity in bonding (e.g. air bubble)
- Cleaning wipes / finger prints
- Particle inclusion / scratch / fibers
- Backlight non-uniformity

- Light creep around layers, leaking in from the edges
- Pressure applied by the display casing
- Stress applied by deformation of the display module
Many Flavors of Mura

• Each Mura type has its own characteristics and requires a specific analysis algorithm to test

• Often a combination of different Mura are present

Clustered Mura  Line Mura  Large Scale Mura  LED Mura  Spot Mura
Corporate Quality Standard

Often driven by
- Marketing
- Sr. Management
- Customer Complaints
- Cost of avoiding

Objections to specific mura types may vary over time
Mura Testing with TrueTest™

• Isolate Different Types of Mura
Mura Testing with TrueTest™

• Isolate Different Types of Mura
• Score the Different Mura
Mura Testing with TrueTest™

- Isolate different types of Mura
- Score the different Mura
- Pass/Fail test the different Mura
Four Ingredients of Mura Analysis

1. Measurement Image
Displays often have small gradients (Mura) on-top of a large gradual slope

2. Local Contrast Image
Remove the large-scale gradients (and/or noise) from the Measurement Image
Four Ingredients of Mura Analysis

3. Standard Spatial Observer
Optionally, the Local Contrast Image can be processed by an algorithm that describes a Standard Spatial Observer

4. Weighting Mura Defects
Analysis with Weighting & Filtering of different types of Mura defects
Filtering & Weighting Mura Defects

Filter Mura on local contrast value

Distinction between bright and dark Mura

Filter on Mura shape (circularity / line shape)

Filter on Mura surface area

Treat groups of Mura as a single defects

Filter Mura on position in the image

Filter on color

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Mura Testing in TrueTest™

- Specialized analysis for each Mura type
- MAKRO style testing of the whole Mura spectrum
- Pass/Fail testing for each Mura type
- Export of (quantified) test values for statistical analysis

TEST SEQUENCE

1. Black Mura
2. Edge Mura
3. Spot Mura
4. Line Mura
5. Corner Mura

FAIL
FAIL

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TrueTest™ Examples

**Black Mura** consists of large blemishes grouped together. TrueTest™ finds the mura, highlights it and quantifies it. Quantification can be in local contract ratio, JND or a customer specific manner.

**Butterfly Mura** consists of blemishes in the corners that are bright (or dark) compared to the edges. Here the butterfly mura is shown on a “local contrast” image.
**LED Mura** consists of bright, evenly spaced blemishes at one edge of the display. They often vary in shape.

**Edge Mura** are bright blemishes on the edges of the display that is easily seen when the display is dim.
Spot Mura are circular or non-circular blemishes. One criteria for the test is the circularity of the blemish. In this example only circular blemishes are considered mura.

Light Leakage consists of different size bright areas near the edge of the display. They typically appear when the display is set to black or a very dark pattern. This is typically the result of mechanical stress in the LCD layer.
The **Corner Mura** test will only look for a bright blemish in the corner that is more easily detectable with the human eye when the display is dim. This may occur when the LCD is pressed upon by the display casing, but could have other root causes.

**Diagonal Line Mura** (or diagonal band mura) is an extended blemish that can be oriented in any direction. This analysis can also be used for “rubbing mura” and could potentially be set to only look for lines in a specific angular span.
Mura Testing to Human Perception

PASS
Mura Noticeability Factors

**Mura Context**
- Local contrast of the Mura defect
- Mura Size, Shape, Orientation
- Position on the display
- Neighboring Mura
- Display size

**Inspector Context**
- Experience (perceptual learning)
- Light & Color Sensitivity
- Mental state (e.g. fatigue)
- Environment (e.g. room illumination)
- Yield pressure
1-Person Quality Judgment

- Large judgment error
Group-Average Quality Judgment

- Reduced judgment error
- Expensive

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TrueTest™ Matching Human Judgment

Displays sorted to quality

Group-Average Quality Judgment
Matched TrueTest™ Judgment
Precise Scoring of Display Quality

1-Person Quality Judgment

TrueTest™

Display Quality Distribution

Fine-Tuning of Pass/Fail
Trending Display Quality Over Time

Exported data allows trending display quality

Tracing mura defects to changes in production
Benefits of TrueTest™ Mura Inspection

• Quality judgment equivalent to a group of human inspectors
• Low cost
• Repeatable test results
• High-consistency between test setups
• Common quality judgment between OEM & Supplier
• Fine-tuning of Pass/Fail criteria
• Easily scalable to high-volume testing
• Statistical analysis on different display defects
• Easily adaptable to a change in Quality Requirements
Testing to the Black Mura Standard
Black Mura Standard

Content: Uniformity measurement standard for Displays

Standard Body: the German “Automotive working group displays” – i.e. a collaboration between BMW, Volkswagen, Audi, Daimler and Porsche

Distribution: The measurement standard is available through the German Flat Panel Display Forum (DFF / www.displayforum.de)

TrueTest™: Testing to the Black Mura standard is adopted in TrueTest™ software
Objectives of the Standard

• Open Standard
  The test method is available to everyone

• No Preferred Equipment Supplier
  The test can be performed with test instruments available from various suppliers

• Simple Interpretation
  The test method should be easy to understand, i.e. the standard document speaks for itself
Test Method Outline

Luminance Gradient is obtained by the derivative of the Luminance image

The Luminance Gradient in any direction is approximated by \( \sqrt{X_{\text{slope}}^2 + Y_{\text{slope}}^2} \)
Test Method Outline

Assuming Weber’s Law is Applicable

- Small increment on a small load: noticeable
- Same increment on a large load: may not be noticeable

\[ \frac{\Delta W_{\text{notice}}}{W} = \text{constant} \]

The maximum (relative) gradient is searched for both a bright- and dark-state display

\[ \left( \frac{L_{\text{gradient}}}{L} \right)_{\text{max}} \]
Black Mura in TrueTest™

Pass / Fail test on:
- Average Luminance (Bright State Display)
- Contrast Ratio (Bright vs. Dark)
- Max. gradient relative to white
- Max. gradient relative to black
One Doesn’t Exclude the Other

Black Mura as part of a more elaborate display test
Comparing Mura Test Methods

**Black Mura**

- Analysis method is **open** and well documented
- Measurement **Standard**, i.e. the same for everyone
- **Not exclusive** to Radiant, or any other supplier of photometry equipment
- Available in TrueTest™ software

**Radiant Developed Mura Testing**

- Analysis method **exclusive** to TrueTest™ software
- User **adjustable & configurable**
- Elaborate Mura testing
Comparing Mura Test Methods

- Testing **Mura + Background Gradient**
- Error is limited by display uniformity requirement

- Testing **Mura only**
- Large-scale gradients are not noticeable
- Mura analysis is performed on a Local Contrast Image
Comparing Mura Test Methods

- Black Mura
  - No differentiation between different Mura types
  - Spatial observer not included
  - Unwanted Pass / Fail

- Radiant Developed Mura Testing
  - Adjustable sensitivity to different Mura types
  - Allows correlation to Human Inspectors

Same Gradient / Same Quality

Same Gradient / Different Quality

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Comparing Mura Test Methods

**Black Mura**

- XY-axis alignment required between display and CCD pixel grid
- Time consuming

**Radiant Developed Mura Testing**

- Rotation correction of the display area through image processing
- Convenient positioning of the DUT
- Deliberate misalignment can reduce Moiré
Comparing Mura Test Methods

Black Mura

- Moiré removal by defocusing

Radiant Developed Mura Testing

- Moiré removal by Dynamic Filtering
- Analysis on a sharp image
- Image can be used for high-resolution analysis (e.g. testing for dead pixels)
Summary

- Radiant offers solutions for various Automotive Applications
- TrueTest™ software offers a total solution for display testing (OEMs & Suppliers)

- Many flavors of Mura
- Specialized Mura analysis functions
- 4 ingredients of Mura testing
- Matching TrueTest™ to Group-Average Human Inspection
- Precise grading and trending of display quality

- Testing to the Black Mura standard in TrueTest™
- Comparing the Black Mura method to Radiant Mura test methods
- Black Mura as part of a more elaborate display test
THANK YOU

If you have questions regarding this topic or presentation, please contact us at Info@RadiantVS.com