HDR Cameras

Linear and non-linear

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GLOBAL REACH...

worldwide operational and commercial presence
with distribution to more than 40 countries
RESEARCH & DEVELOPMENT

*a unique blend of technologies & competencies*

- Area scan and line scan camera technology.
- Analogue-to-digital circuit design.
- Software engineering.
- Image pre-processing techniques.
- High-speed interfaces.
- Optical knowledge.
- Imager and multi-imager technology.
High Dynamic Range Imaging (HDR) Contents

- Large pixels
  - Area
  - Full well capacity
  - Binning

- Multi-images
  - Sequential
  - Instantaneous

- CMOS multi-slope
WHY HIGH DYNAMIC RANGE?

Imagers show limited dynamic range:
WHY HIGH DYNAMICS RANGE?

Extended dynamic range:

Image fusion, multi-slope or perhaps a large pixel well with low noise.
APPLICATION SLIDES
Static and dynamic applications

- Medical imaging
- ITS
- PCB inspection
- Film scanning
- Print inspection
- Glass inspection
- Device inspection
- Aerial photography
- Vegetation analysis
DYNAMIC RANGE

Definition

The imager dynamic range is given by

\[ DR = 20 \log \left( \frac{N_{\text{sat}}}{N_{\text{dark}}} \right) \text{ [dB]} \]

- \( N_{\text{sat}} \): The amount of electrons collected at pixel saturation level
- \( N_{\text{dark}} \): The pixel noise in electrons in dark

\[ \text{NSAT: The amount of electrons collected at pixel saturation level} \]
\[ \text{Ndark: The pixel noise in electrons in dark} \]
DYNAMIC RANGE
Non-cooled imagers

Dominating factors

- For low light
  - Imager noise and readout noise dominates
  - To improve optimize: QE, Pixel Area, Imager Noise, Readout Noise

- For bright light
  - Photon and shot noise dominate
  - To improve optimize: QE, FWC (Pixel Size)
• One readout amplifier per pixel
• Better response (sensitivity)
  – Larger surface area collects more light with same lens F-number
• Larger pixel well capacity
High sensitivity monochrome CMOS line scan camera:
- Based on custom CMOS sensor
- Resolution 2048 pixels
- Pixel size 20 µm x 20 µm
  - 60 ke− (responsive mode)
  - 360 ke− (high DR mode)
- Maximum line rate 80 klines@12 bit output
- Camera Link, CoaXPress or GigE interface
- Camera settings through interface or Ethernet port
TWO IMAGER MODES
Increasing the image contrast in low light scenes

HIGH DYNAMIC RANGE MODE
Quantum Well (360 ke⁻¹)

RESPONSIVE MODE
Quantum Well (60 ke⁻¹)

8-bit depth resolution
100% white
100% black

BETTER IMAGE CONTRAST IN LOW LIGHT SCENES
TWO SENSOR OPERATION MODE

*Increasing the image contrast for bright scenes*

**HIGH DYNAMIC RANGE MODE**

- Quantum Well (360 keV)

**RESPONSIVE MODE**

- Quantum Well (60 keV)

Noise level
PIXEL BINNING

Trend is towards smaller pixels but...

HW binning
- Down to one readout AMP per binned pixel
- 2x2 binning: down to $\frac{1}{2 \times 2}$ readout noise

Digital binning
- One readout AMP per pixel
- 2x2 binning: down to $\frac{1}{\sqrt{2 \times 2}}$ readout noise

JAI SPARK-5000 CMOS
Key features:

- ALC - automatic level controlled exposure mode
- Built-in LUT for gamma and other transformations
- On-chip binning and multi-ROI functions
- Selectable P-iris or 3-axis analog lens control standard
- In-camera CMOS pattern corrections -> Better image quality
- Auto-scaling A/D front-end -> Better control over light
- 4-channel analog gain section for individual Bayer color control -> Better color control
- Color and Monochrome versions
- Multiple interfaces -> More choices to fit application requirements
MULTIPLE EXPOSURES

- HDR mode (high dynamic range) - by adjusting the exposure separately for two images it is possible to resolve +16 bit by image fusion with good precision dependent on the brightness of the object.
MULTIPLE EXPOSURES

Single imager

Sequentially recording requires static or semi-static object

Two or more images shifted in time
- color or monochrome - with different

• Exposure (linear)
• Gain
• Lighting

Followed by image fusion

Up to 10 settings in non-volatile memory
ELITE SERIES
Lowest noise and highest sensitivity

KEY FEATURES AT A GLANCE

- High speed CCD with excellent image quality.
- Low noise operation.
- Increased sensitivity and better NIR response.
- ALC (Auto Level Control) and P-iris control.
- Programmable 3-axis control for zoom, focus and iris.
- 8/10/12-bit depth.
- 3 x 8 (24-bit) in-camera color interpolation. (@ 15 fps).
- Horizontal and vertical binning modes for enhanced sensitivity.
- HD-mode.
- Exposure from 1/100,000 to 8 seconds.
- LUT, gamma compensation, shading correction, blemish compensation and more.
- Common JAI SDK and Control Tool.
MULTIPLE EXPOSURES

Instantaneous recording - works with moving objects

Two images acquired simultaneously
- color or monochrome - with different
  • Exposure (linear)
  • Gain
Followed by image fusion
MULTIPLE EXPOSURES
2-CCD/CMOS prism

Prism filter characteristics

Visible 1 (transmission)
Visible 2 (reflection)
MULTIPLE EXPOSURE

2-CCD camera

AD-132GE

- 2-CCD high dynamic range color camera
- Two Bayer color CCDs (1/3”) mounted on an optical prism
- 1296 x 966 active pixels per channel
- Choice of built-in image fusion or SDK post processing routines to achieve nearly 120 dB dynamic range
- 31 fps operation for HDR
- Separate high-speed (62 fps) and high S/N modes also included
- GigE Vision/GenICam compliant with 8-bit, 10-bit, or 12-bit per channel output
- Programmable exposure from 11.49 µs to 31.761 ms in one-line increments
- Auto shutter from 1/31 to 1/366 s
- Analog video output for auto-iris lens control
- Programmable 25-in/14-out GPIO module
CMOS HDR mode

Linear response

Output signal

Saturation level

# of photons
CMOS HDR mode

Linear response

Output signal vs. # of photons

Saturation level
CMOS HDR mode

Piecewise linear response – “multi slope mode”

Saturation level

Output signal

# of photons

Kneepoint
Slope 2
CMOS HDR mode

Piecewise linear response – “multi slope mode”

What about color?

Saturation level

Output signal

Kneepoint Slope 2

Kneepoint Slope 3

# of photons

# of photons
HDR FUNCTION* SP-20000

Increasing the dynamic range with multi slope

Original scene

Exposure time is set so pixels get enough light to see details in the darker areas of the scene. In areas where pixels are receiving more light with risk of pixel saturation, the exposure time is restricted with the dual slope function.

Resulting HDR image

*Monochrome only
Key features:

- 8/10/12-bit output.
- In-camera CMOS pattern corrections.
- ALC - Automatic Level Controlled exposure mode.
- Programmable LUT, gamma correction, flat field correction and blemish compensation
- Single and multi-ROI functions.
- On-chip HDR functionality
- 10 µs (1/100,000) to 8 seconds exposure control in 1 µs steps
- Color and monochrome versions.
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Thank you