A fully open source stack for MIPI cameras.

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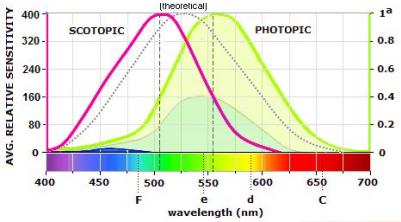
Introductions

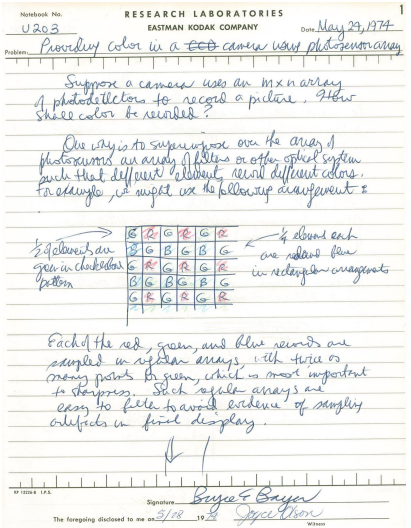
- Bryan
  - Kernel engineer @ Linaro (Qualcomm Landing Team)
  - Maintainer of Qualcomm CAMSS driver
  - https://git.codelinaro.org/bryan.odonoghue/kernel
  - https://github.com/0xB0D
  - bryanodonoghue @ #linux-media #linux #aarch64-laptops #libcamera #linux-msm

What this talk is about

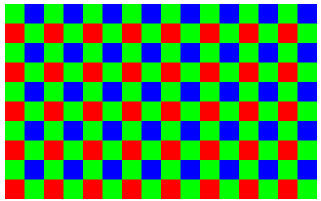
1. Bayer Encoding
2. What is a Hard ISP - what are the 3As ?
3. SoftISP in Libcamera - what’s the problem we are trying to solve ?
4. Pipewire and Libcamera
5. Future plans
6. Demos

Bayer Encoding

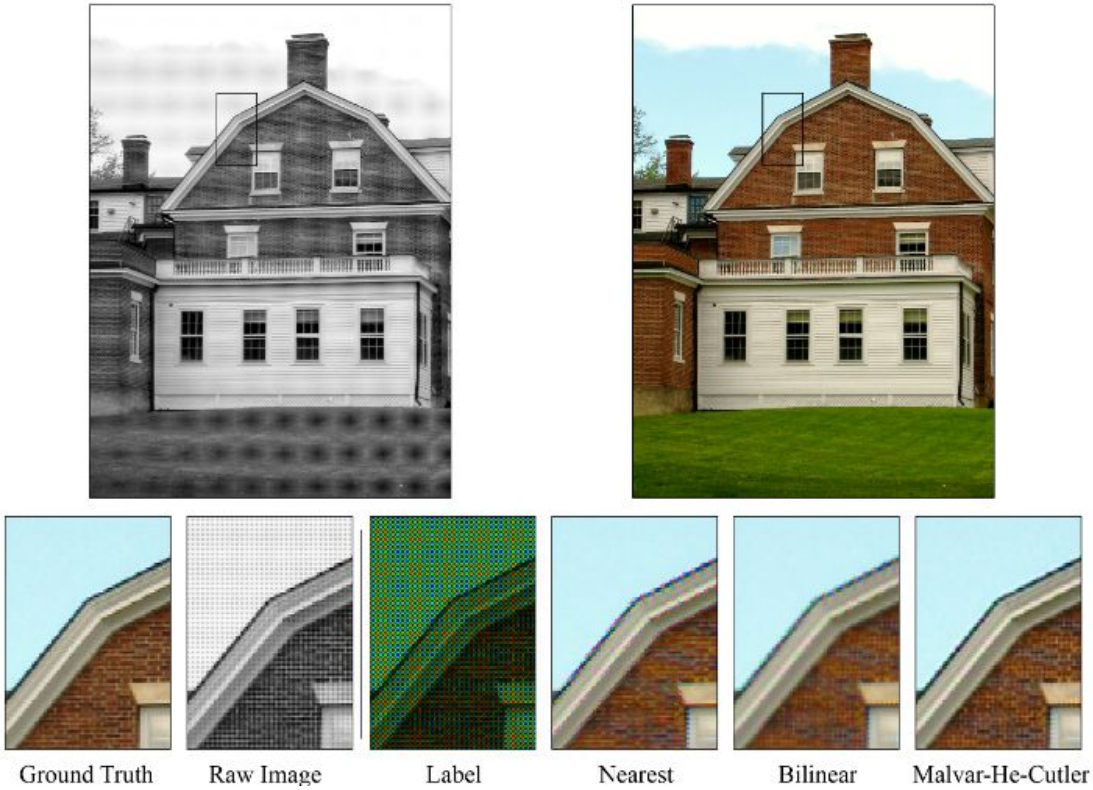




- Human eye is composed of “rods” and “cones”
  - Rods Scotopic
  - Cones Photopic - sensitive to light around 550 nm
  - Most sensitive to “greenish yellow” colours
- Most RGB sensors don’t capture RGB
  - Contain monochrome sensors
- Sensors overlaid with a “mosaic” pattern of Red, Green, Blue
  - Bruce Bayer Eastman Kodak 1974
  - Bayer encoding
- Problem - each pixel contains only one colour
  - Approximate based on proximate pixels
  - Called “interpolation”
- Methods
  - Label
  - Nearest
  - Bilinear
  - Malar-He-Cutler



Bayer encoding / decoding visualised



Source: McGuire, Morgan “Efficient, High-Quality Bayer Demosaic Filtering on GPUs“

What is a HardISP - what are the 3As ?

- HardISP
  - Hardware Image Signal Processor
  - A specialised silicon or firmware block - usually both
  - Principle of data locality - process close to sensor input
- Debayers
- Implements 3As
  - Autofocus (AF)
  - Auto White Balance (AWB)
  - Auto Exposure / Gain (AG)
    - Usually MIPI sensors have an analogue and digital gain
- More advanced “secret sauce” algorithms
  - Sensor tunings (joking but not joking)
  - Skin tones
  - Low light noise reductions
  - Contrast
  - Lens flare reductions
  - Black mirror universe bridal poses (again not joking)

SoftISP - what problem are we solving ?

- Reluctance/refusal of some vendors to disclose “secret sauce”
- Raw Bayer data delivered to userspace -> IPU6 Intel, CAMSS Qcom, others
- We receive bayer encoded data to userspace and that’s it.
- Desire to have a generic open source implementation that solves the same problem across platforms.
- Libcamera
  - Defacto OSS standard - RPI4 and RPI5 as example
  - Pipewire integration
  - Hide away details of V4L camera pipelines
- Linaro initiated project to upstream a CPU SoftISP
  - Recipes Paris
  - Guidance from libcamera people on how
  - Andrey Konovalov
  - V1
- Red Hat engineers joined 2-3 months later
  - Hans de Goede
  - V2 onwards
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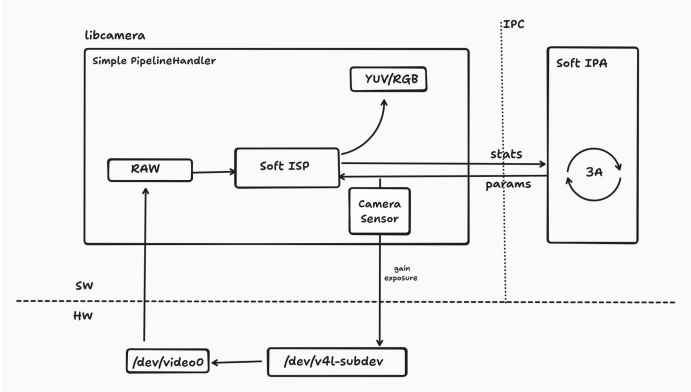

Pipewire - application camera access

- MIPI cameras require complex pipeline configuration and extra processing (3A-s) in userspace
- libcamera takes care of this for applications
- Directly opening /dev/video0 no longer works, instead applications need to go through libcamera somehow
- Some distributions are moving to a model where applications run from a sandbox (flatpaks)
- Using pipewire to access cameras solves both the sandboxing and go to through libcamera issues
- Upstream libwebrtc has full support for pipewire cameras
- Jan Grulich (Red Hat) has landed support for pipewire cameras in Firefox 122

Future plans - Better, Faster, Cheaper

- GPU acceleration - OpenGL
  - Faster and uses less energy
  - Reuse upstream GLSL fragment/vertex shaders already in libcamera
  - https://gitlab.freedesktop.org/camera/libcamera-softisp/-/tree/SoftwareISP-v05-opengl-v1-bod
  - Reuse IPA / 3A from CPU if possible
- GPU acceleration - OpenCL/Vulkan
  - Some GPUs - Imagination are reported moving Vulcan only
  - An OpenCL or Vulkan compute shader to debayer may be required
- Image quality enhancements:
  - Contrast enhancement (CPU and GPU, e.g. Y histogram equalization)
  - Flicker controls (CPU and GPU)
  - Color Saturation enhancement (GPU)
  - Lens shade correction (GPU)
  - Lens shape correction (GPU)
  - Noise reduction (GPU)
- Defect pixel correction (GPU)

References

- McGuire, Morgan “Efficient, High-Quality Bayer Demosaic Filtering on GPUs“ https://casual-effects.com/research/McGuire2009Bayer/bayer-jgt09.pdf William’s College 2009
- Mosiac pattern graphic By Amada44 - Own work, Public Domain, https://commons.wikimedia.org/w/index.php?curid=3483669
- Scotopic / Photopic graphic https://www.researchgate.net/figure/Curve-of-the-spectral-sensitivity-of-the-human-eye_fig1_329747660
- 3A description https://gimoonnam.github.io/imageprocessing/3A-initiation/
- Adorno, José “This iPhone photo of a bride shows a crazy Matrix glitch – but it’s easy to explain” https://bgr.com/tech/this-iphone-photo-of-a-bride-shows-a-crazy-matrix-glitch-but-its-easy-to-explain/
- Jan Grulich’s blog posts on Firefox pipewire camera integration
- https://jgrulich.cz/

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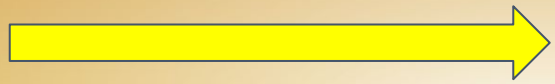
Thank you

Slides?



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