Implementing Embedded Vision: Designing Systems That See and Understand Their Environments

Improving Image Understanding by Improving Image Quality

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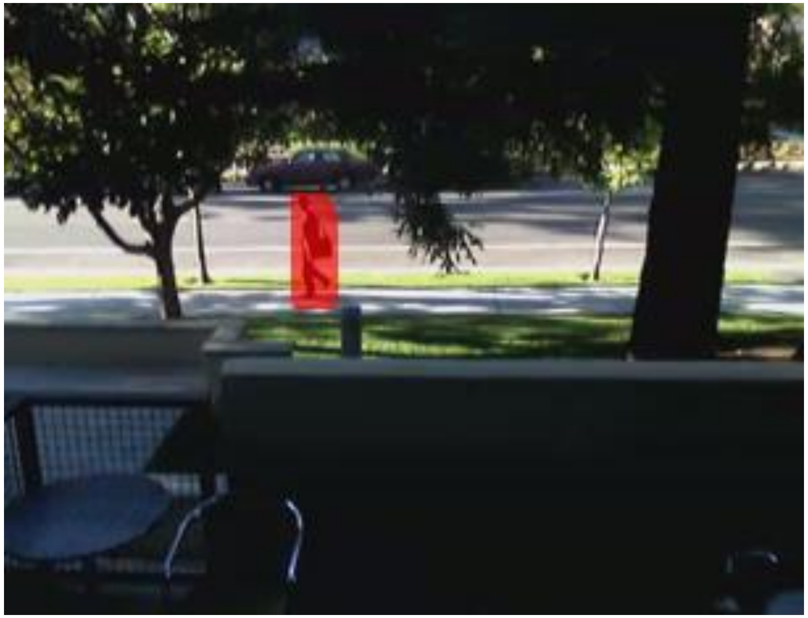
Introduction

- This presentation gives an overview of camera image signal processors (ISPs) and discusses interaction with embedded vision applications
- We highlight how ISP processing may help or hinder performance of embedded vision post-processing
- This material should help designers of embedded vision systems understand how the ISP impacts the quality of the data input into vision algorithms

What happens to the pixels before the vision algorithm gets them?



What does an ISP do?

- RAW (usually Bayer) data comes directly from the sensor and may be best for embedded vision
- But often this isn’t available: IP cameras output compressed YUV after much processing
- Processing can reduce noise, control dynamic range, adjust color balance etc
- ISP may be inside the sensor module or in the camera SoC

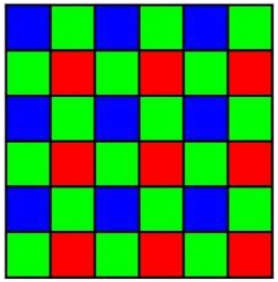
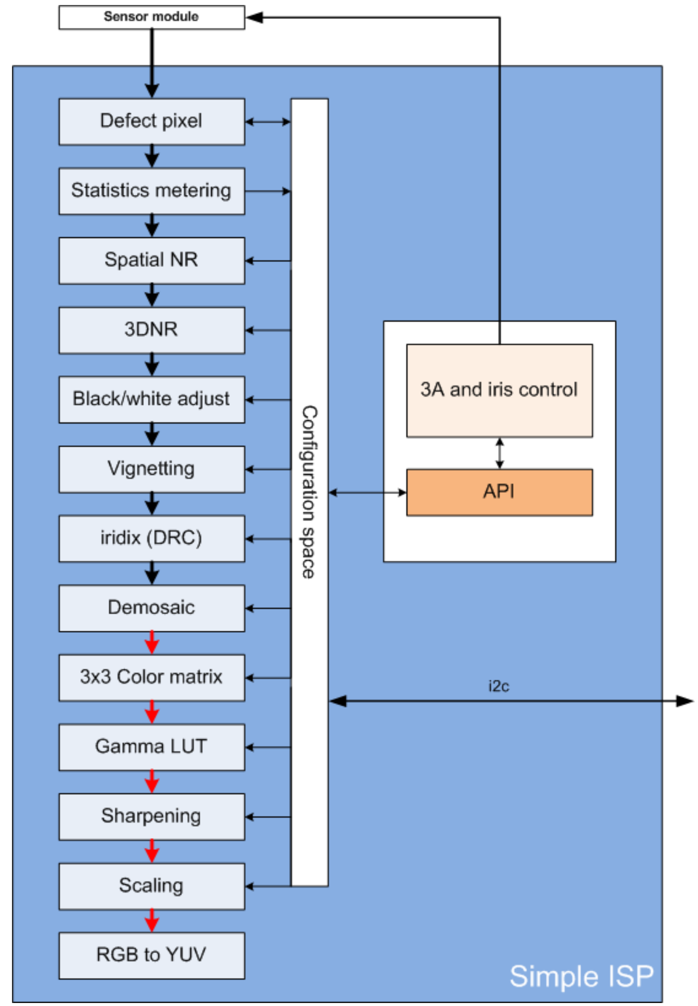


Image Signal Processors

A lot of processing is done on raw pixels to produce realistic images



Example ISP stages

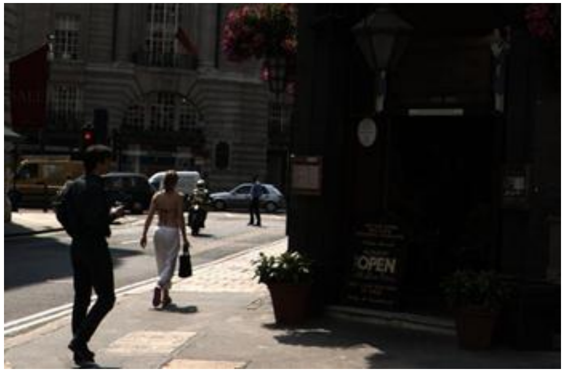
- Bayer demosaic
- Spatial and temporal noise reduction
- Dynamic range compression
- Color correction
- Sharpening
- Video compression

What does this mean for embedded vision?

- To produce realistic images, pixel data is heavily adjusted from original sensor pixels
- Typically, vision algorithms have no information on what transformations have been applied
- These transformations may help or hinder performance of vision algorithms

Example: dynamic range and edges

- Cameras always apply dynamic range compression (DRC) to handle real-world illumination

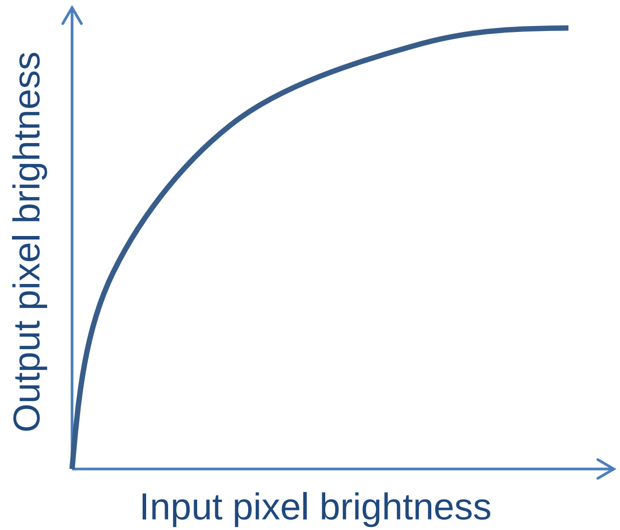


Before DRC

After DRC

Dynamic range and contrast

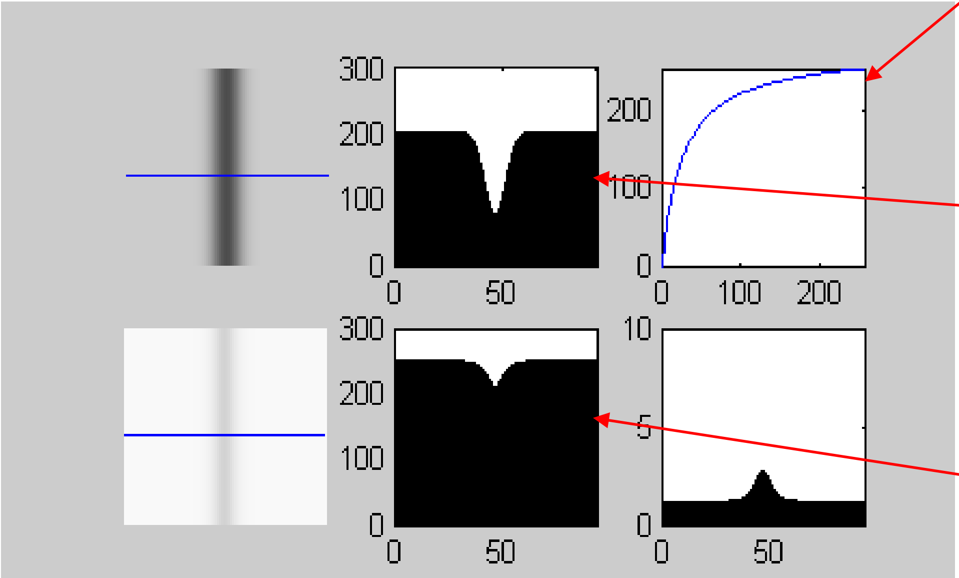
- DRC = global **contrast reduction**



- What happens to **local** contrast?
  - An edge is a local contrast feature
  - Edges are often important in embedded vision algorithms
  - How does DRC affect edges compared to original RAW data?

Effect of DRC on an edge

- DRC smears edges
  - Nothing to do with sharpness



This gamma…

distorts this feature..

..into this feature

What does this mean?

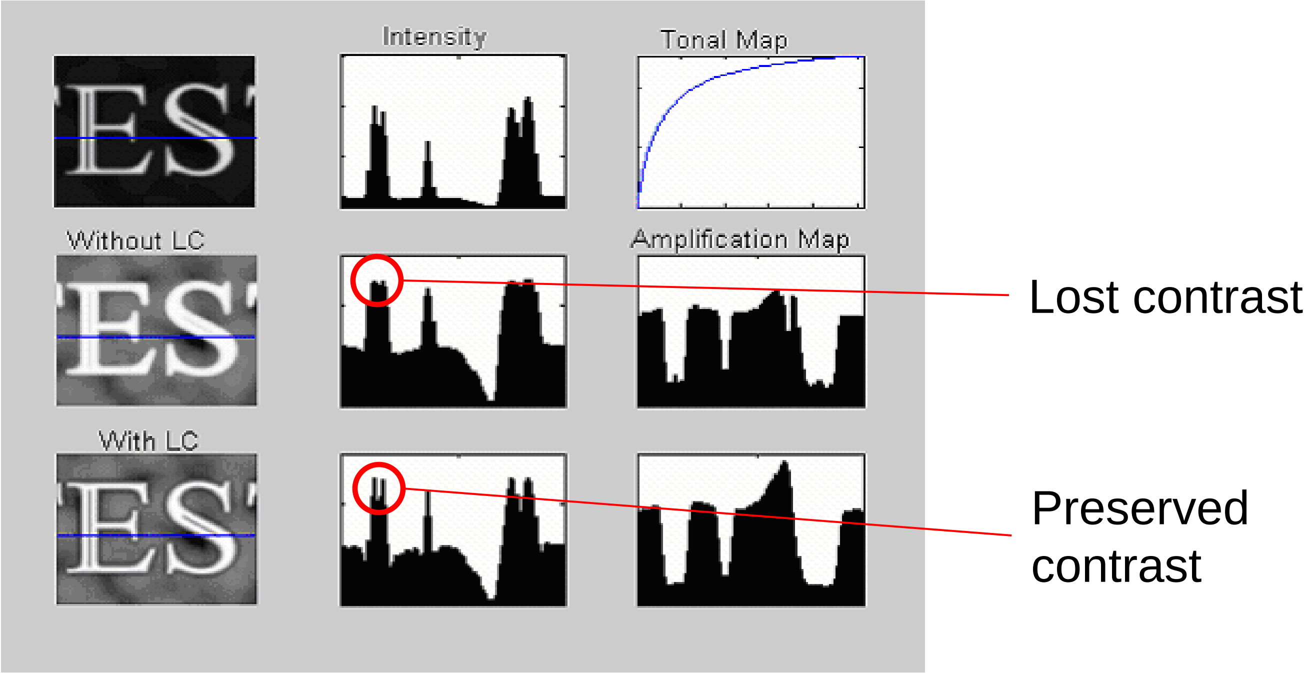
- An edge moving from a shadow to a highlight is not preserved, if DRC is applied
- Cannot be recovered by sharpening
- Any threshold-based edge detector will be compromised

How to deal with this problem?

- Work directly on RAW data; or
- Apply specific algorithms to preserve local contrast

Effect of local contrast preservation

- Modify DRC module to preserve local contrast



DRC vs contrast: summary

- DRC is important to preserve real-world detail in standard video output
- But special treatment should be made in ISP to avoid degrading computer vision post-processing

Other considerations

- **Noise reduction** affects noise distribution non-uniformly
  - Cannot rely on a priori separation of signal from noise
- **Automatic white balance** is never wholly reliable
  - Colors are adjusted based on illuminant estimation
- **Automatic exposure control** takes time to converge
  - Depending on scene change and choice of algorithm
- **HDR technologies** capture more but sometimes add artifacts
  - Either motion artifacts or resolution artifacts
- **Video compression** loses information and adds compression artifacts

Conclusion

- In designing embedded vision post-processing systems, it's helpful to understand what the ISP is doing
- An ideal ISP for computer vision differs from an ideal ISP for visualization

The Embedded Vision Alliance

Free Resources on Embedded Computer Vision

The Embedded Vision Alliance web site, at www.Embedded-Vision.com, covers embedded vision applications and technology, including interviews and demonstrations

Register on the Alliance web site for free access to:

- The Embedded Vision Academy—free in-depth tutorial articles, video "chalk talks," code examples, and discussion forums.
- Embedded Vision Insights—bimonthly newsletter with industry news and updates on new resources available on the Alliance website.

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