A Win-Win Camera: Quality-Enhanced Power-Saving Images on Mobile OLED Displays

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Motivation

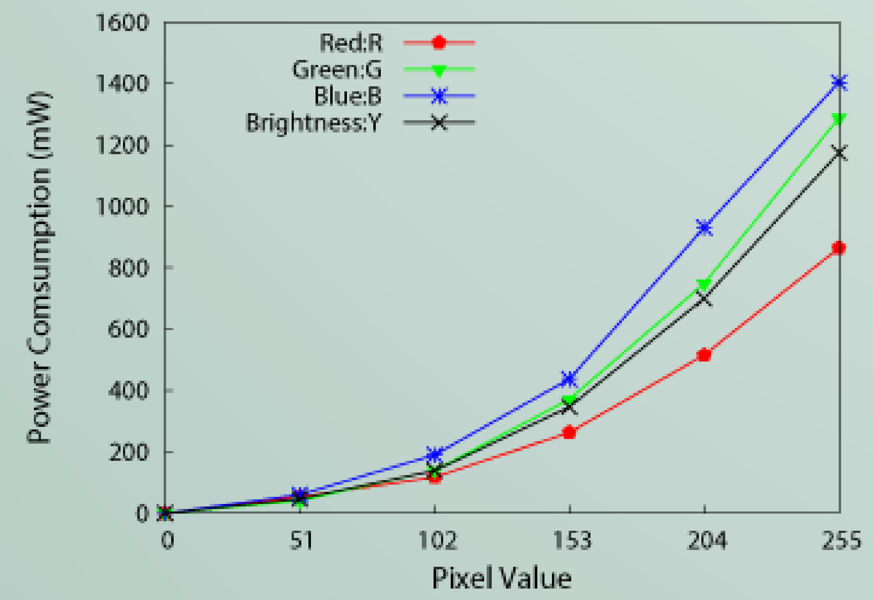
- Existing OLED power-saving techniques change users' visual experience or degrade images' visual quality in exchange for power reduction, or seek a chance to enhance image quality by employing a compound objective function.
- Quality enhancement has its necessity because users are often lack of photographic expertise or lighting conditions are not always ideal.

Contributions

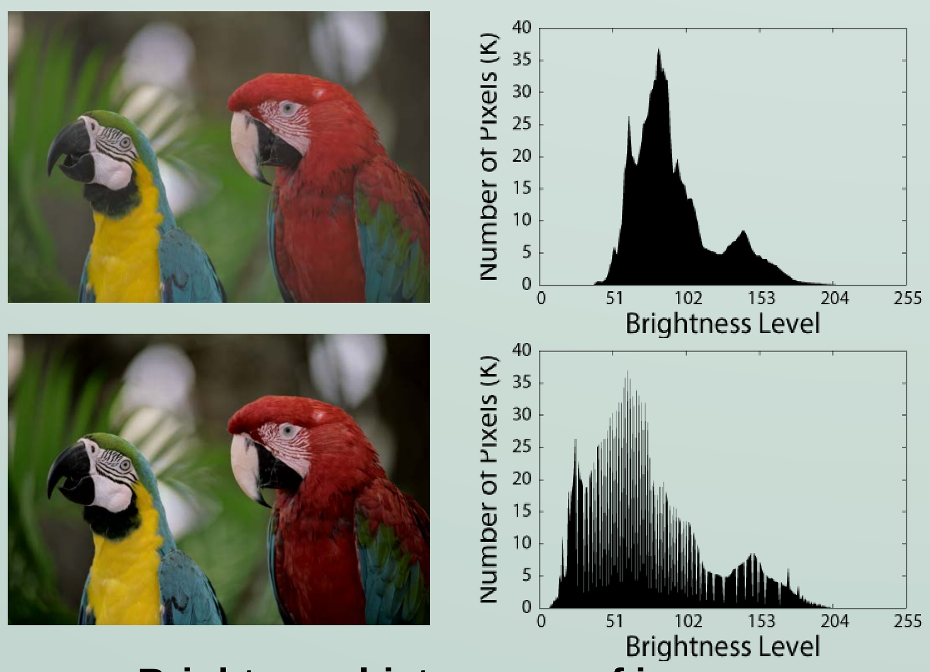
- A win-win scheme that always enhances image quality and reduces power consumption simultaneously.
  - Metrics to assess the profit and cost of potential image enhancement and power reduction
  - Algorithms to transform an image into quality-enhanced power saving versions
  - A practical camera application for practicality validation on commercial OLED devices

OLED Image Display

- OLED power can be reduced by scaling down the brightness levels of pixels.
- Image quality can be enhanced by redistributing pixels' brightness levels to better use the full intensity range.



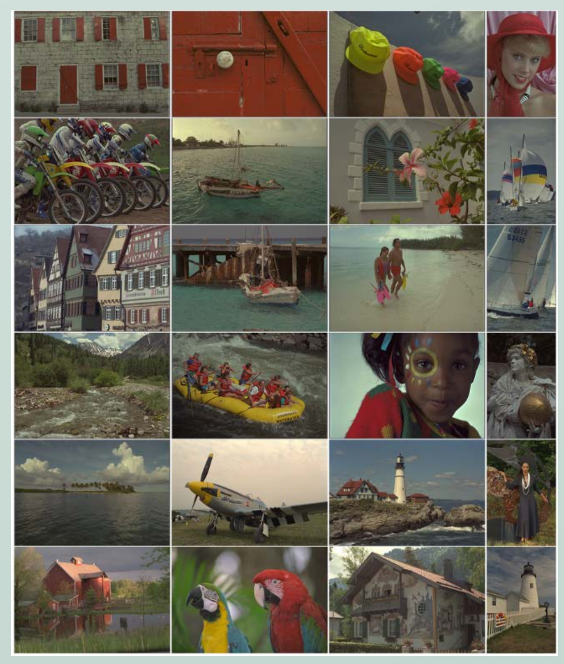
OLED power model (Samsung Galaxy Tab 7.7)



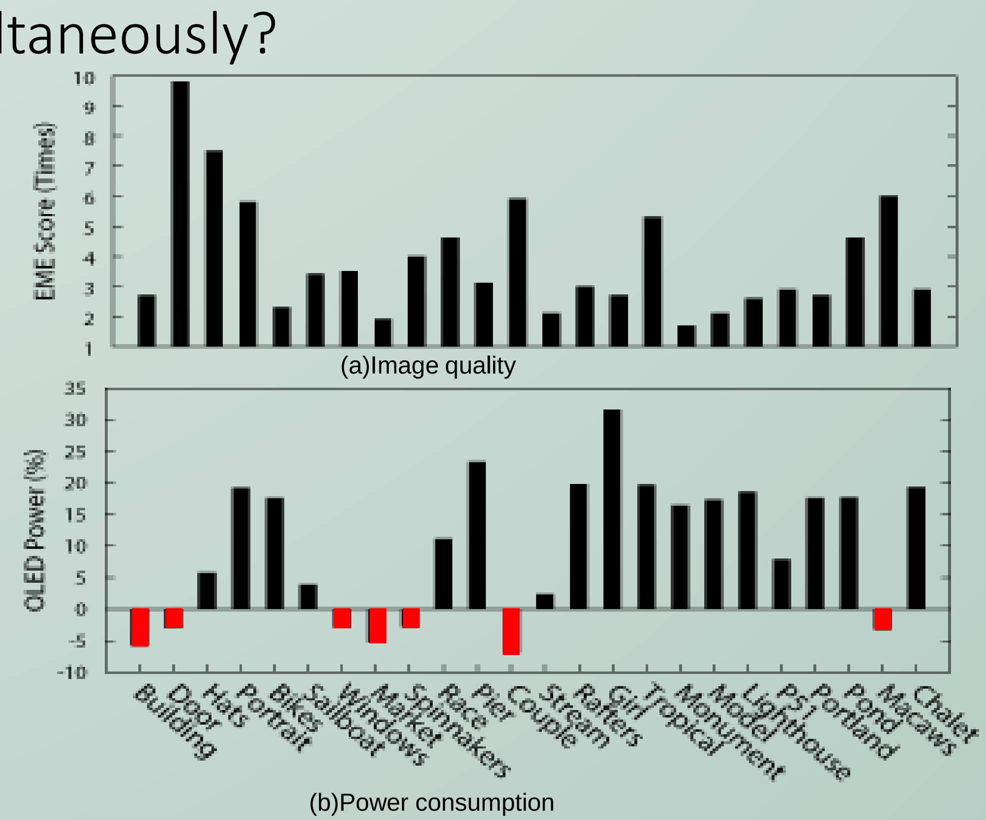
Brightness histograms of images

Visual Quality vs. Power Consumption

- A quality-enhanced image can consume less OLED power than its original image (not significantly though).
- Is there a scheme that always enhances image quality and reduces power consumption simultaneously?



Kodak image database



Results produced by HMA

A Win-Win Scheme

A. Contrast and Power Metrics

- Contrast Metric:
  - Contrast is the difference in brightness that makes some pixels distinguishable from the others: $\boldsymbol{C(H)} = \sum_{i=0}^{255} \boldsymbol{pdf(i)} \times \boldsymbol{\delta(i)}$.
- Power Metric:
  - The power required by an image is the sum of the power consumed by all the pixels: $\boldsymbol{P(H)} = \sum_{i=0}^{255} \boldsymbol{pdf(i)} \times \boldsymbol{e(i)}$.
- Contrast-to-Power Index:
  - Which brightness level to be adjusted? $\boldsymbol{CPI(x)} = \boldsymbol{pdf(x)} \times \boldsymbol{cdf(x)}$ to assess the preferability of increasing level x's distance.

B. Fundamental Algorithms

- Input: A histogram $\boldsymbol{H}$ and a power function $\boldsymbol{e}$.
- Output: The minimum power P_{min}.

1: Compute $pdf(x), cdf(x), CPI(x), \forall x$, based on H
2: Build $\delta(x)$ based on $pdf(x), \forall x$, by WTHE
3: $\delta(x) \leftarrow 0$ if $pdf(x) = 0$, and 1 $otherwise$, $\forall x$
4: Build $\widehat{H}$ based on H and δ
5: while $C(\widehat{H}) < C(H)$ do
6: $\delta(x) \leftarrow \max(\lfloor \delta(x) \times 255 \rfloor, 1)$ for x with the largest $CPI(x)$
7: $CPI(x) \leftarrow -1$
8: Update $\widehat{H}$ based on δ
9: return $P_{min} \leftarrow P(\widehat{H})$

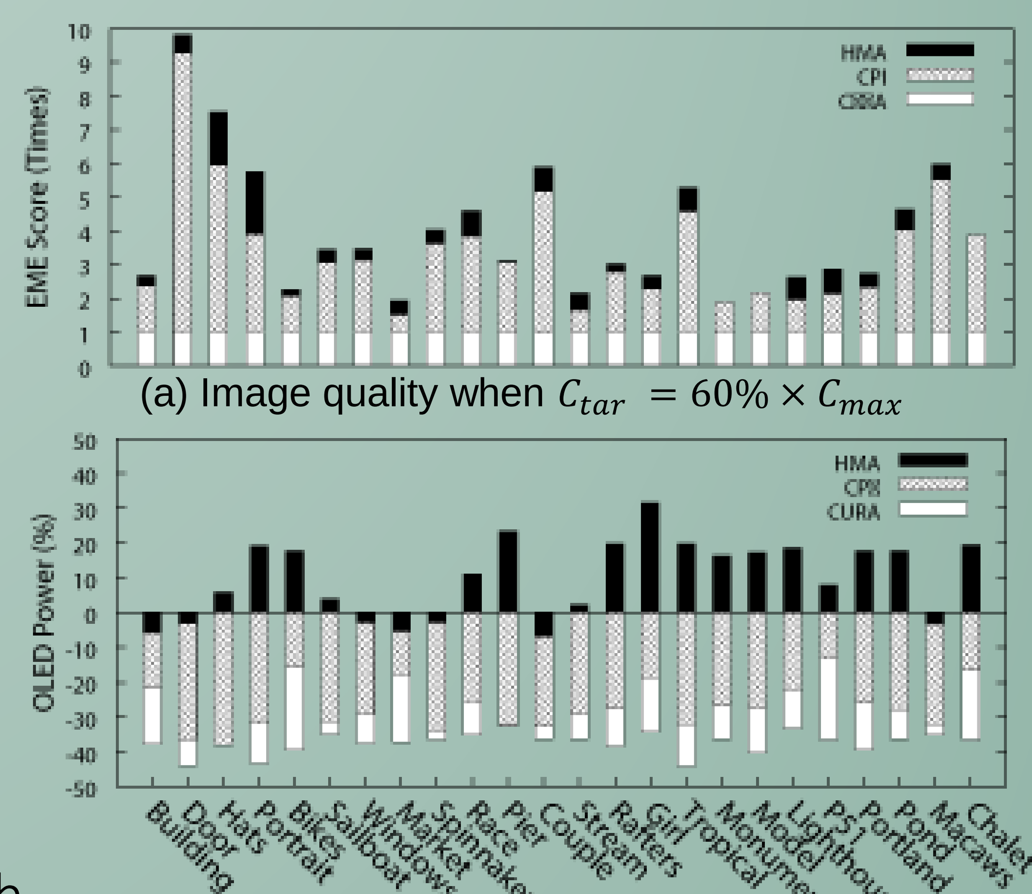
A Win-Win Camera for OLED Mobile Devices

- A stand-alone Android app on a Samsung Galaxy Tab 7.7.
- Transforming a picture takes 96ms, while each subsequent editing takes 14ms.

A snapshot of our win-win camera

Performance Evaluation

- Platform
  - Samsung Galaxy Tab 7.7
- Image Set
  - Kodak image database (24 Images covering a variety of themes and lighting conditions)
- Performance Metrics
  - Quality scored by EME
  - OLED power measured
- Compared Algorithms
  - HMA: Pure image enhancement approach [TIP'09]
  - CURA: Pure power reduction approach [DAC'14]
  - CPI: Our win-win approach
- Numerical Results
  - HMA and CPI increase EME scores by 3.9 and 3.4 times
  - CURA and CPI reduce OLED power by 37% and 27%



(a) Image quality when $C_{tar} = 60\% \times C_{max}$

(b) Power reduction when $C_{tar} = 60\% \times C_{max}$

Conclusion

- Rationale behind our win-win camera
  - Contrast is much more central than the absolute brightness to the image quality perceived by the human visual system.
- Experiment results on Samsung Galaxy Tab 7.7
  - 88% of the image quality enhanced by HMA [TIP'09], a pure image enhancement approach.
  - 73% of the OLED power reduced by CURA [DAC'14], a pure power reduction approach.

(a)Original (b)CPI (EME: 2.3x, PWR: -26%) (c)CURA (EME: 1x, PWR: -39%) (d)HMA (EME: 2.7x, PWR: 18%)