Improving low-light performance through burst photography on mobile cameras

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https://www.youtube.com/watch?v=voceu67Vd3c

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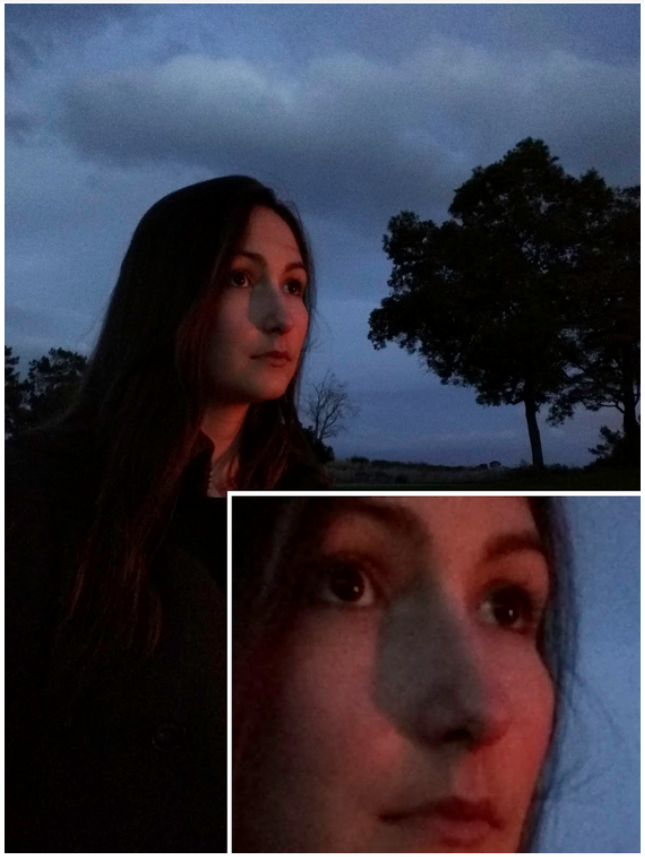
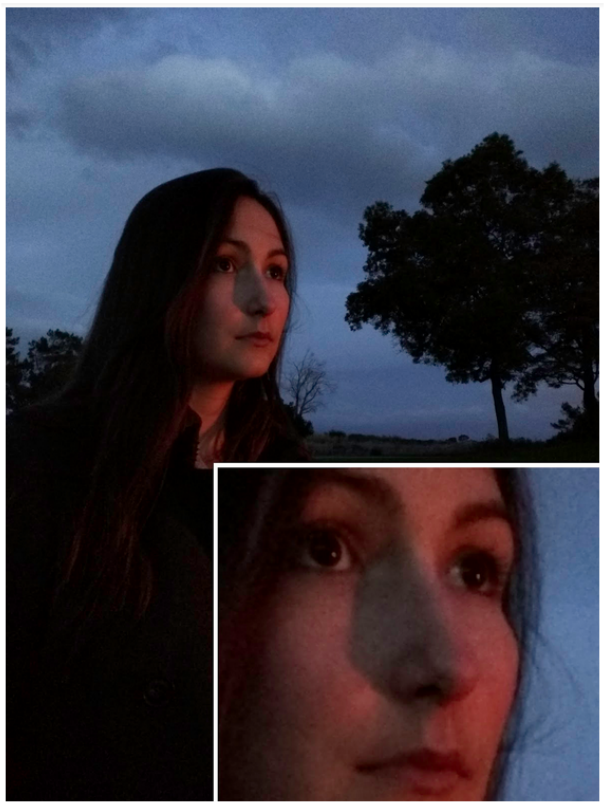
The Problem Space



https://research.googleblog.com/2014/10/hdr-low-light-and-high-dynamic-range.html

[4]

Noise

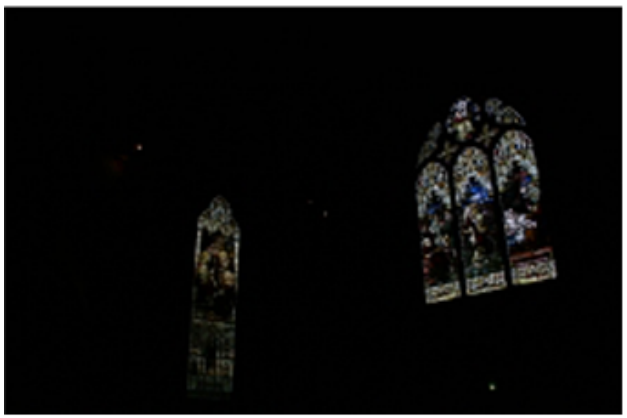


[4]

Background

[4]

Dynamic Range



1/30 Second Exposure

1/4 Second Exposure

2 Second Exposure

https://en.wikipedia.org/wiki/Tone_mapping

High Dynamic Range (HDR)

https://en.wikipedia.org/wiki/Tone_mapping

Burst Capture

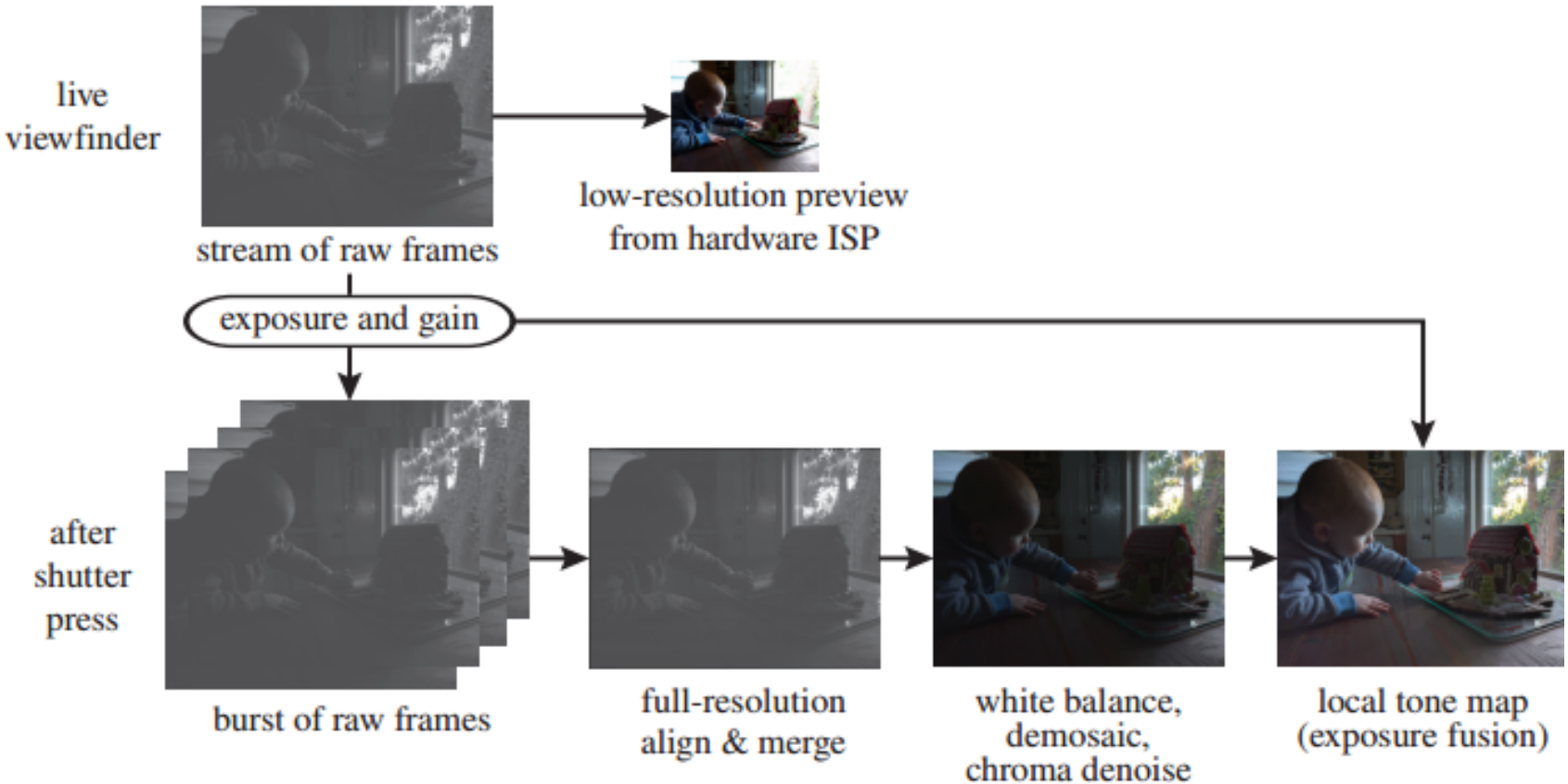
https://plus.google.com/+GoPro/posts/3xyZBmY3rzP

http://www.shoulderpod.com/

Burst Photography

Burst Photography (HDR+)

Overview


live viewfinder
stream of raw frames
low-resolution preview from hardware ISP
exposure and gain
after shutter press
burst of raw frames
full-resolution align & merge
white balance, demosaic, chroma denoise
local tone map (exposure fusion)

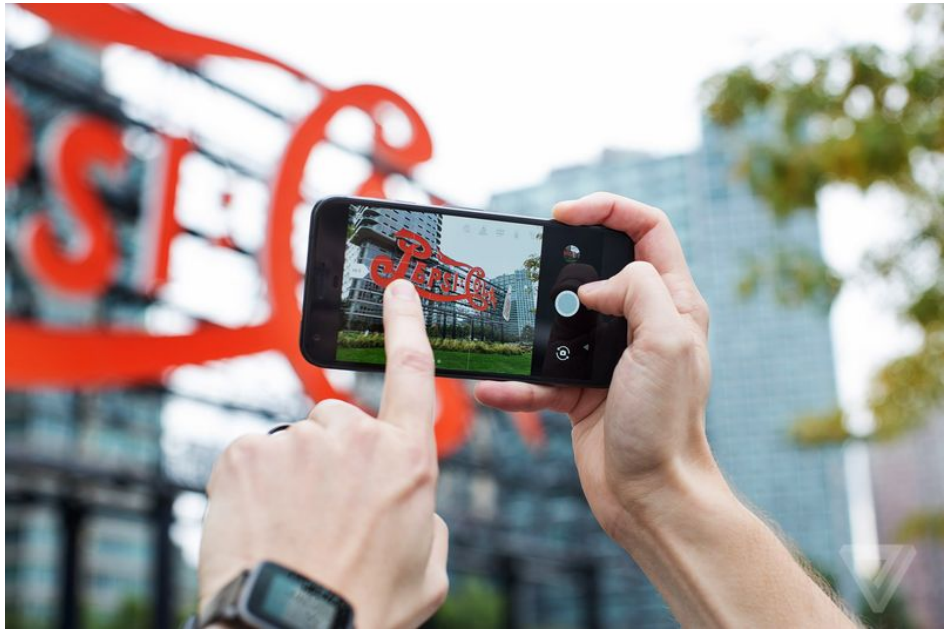
[1]

What is Unique?

- Pre processes image data before capture
- Using RAW file format
- Capturing at a single exposure in burst

Pre-processes

- Analyzing the scene
- What settings to capture with?
- How many photos to take?



http://www.theverge.com/2016/10/18/13315168/google-pixel-camera-software-marc-levoy

RAW

- 3x larger then JPEG
- Contain maximum dynamic range
- Recover overexposed or underexposed areas

http://www.the-photography-blogger.com/index.php/2015/09/05/raw-vs-jpeg/

Single Exposure Capture

- Single exposure at every frame
- Slightly underexposed
- Preserve highlight detail
- Bring out shadow detail later

[2]

Uniqueness

[2]

Image Database

- 5,000 processed images
- Match consumer scenarios
- Search for similar images
- Update camera settings

[2]

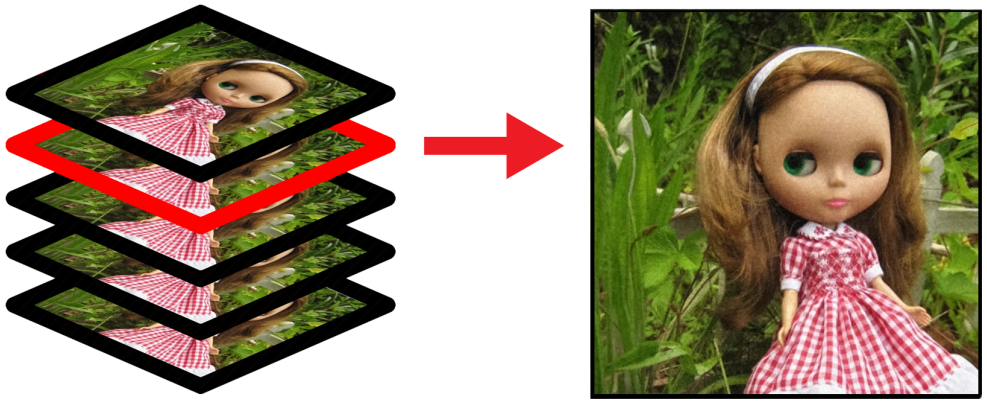
Burst Capture

- Recording frames at 30 fps
- Recent frames stored in temporary memory

http://www.androidauthority.com/google-pixel-xl-review-720243/

Burst Capture

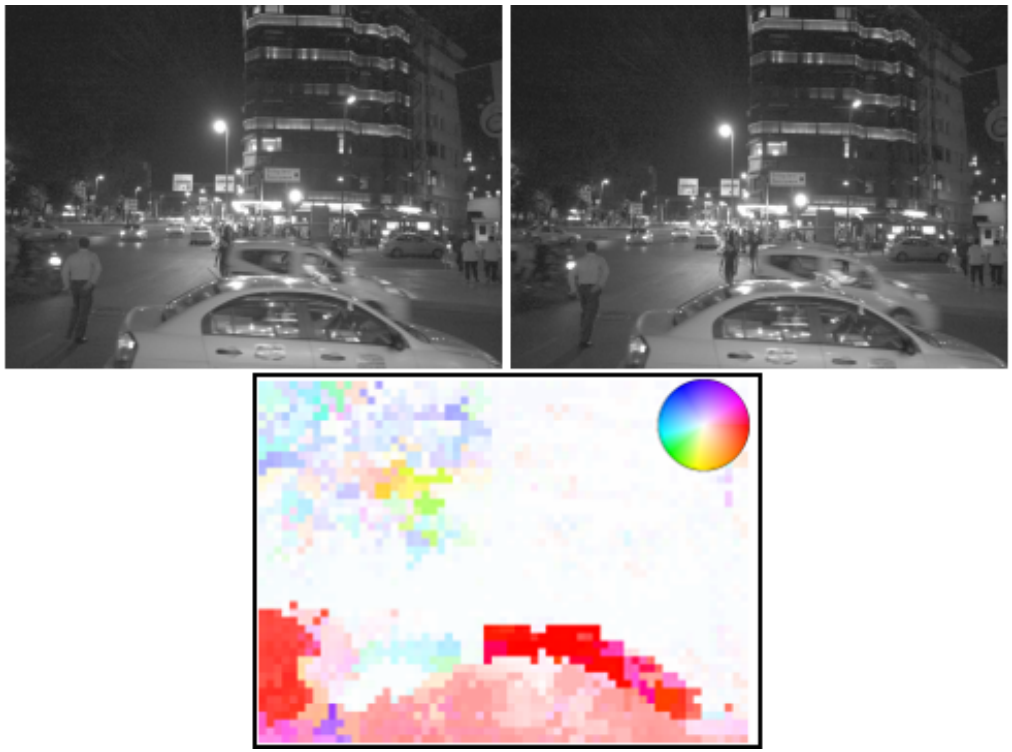
- Burst will capture 2-8 frames
- Frames put in a stack
- Best frame is selected as the reference



[2]

Alignment

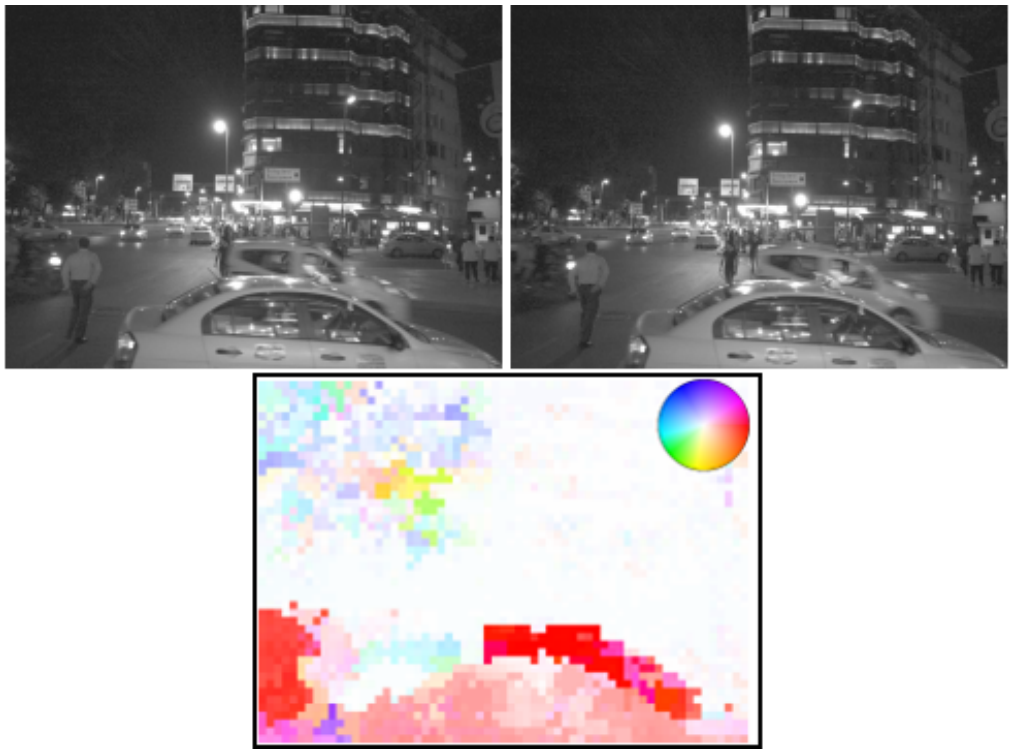
- Frames are converted to gray scale
- 12 mpix image down sampled to 3 mpix image
- Consist of 16 x 16 pixel tiles



[1]

Alignment

- Run two alignment methods
- Hierarchical alignment
- Fast sub-pixel L2 alignment



[1]

Merging Process

- Create a single image from the stack
- Combine good tiles with the reference frame
- Place color pixels over noise pixels
- Need to implement a noise reduction algorithm

Noise Reduction Algorithms

- Algorithms locate high quantity of noise
- Reduce noise values, blending them into the image
- Burst photography implements Discrete Fourier Transformations

https://research.googleblog.com/2014/10/hdr-low-light-and-high-dynamic-range.html

Discrete Fourier Transformations (DFT)

- Isolate noise values
- Reduce without corrupting the image
- Represent overall noise intensity per tile as a single value (ω)

https://cacm.acm.org/magazines/2011/5/107708-self-similarity-based-image-denoising/fulltext

Burst Photography Merging

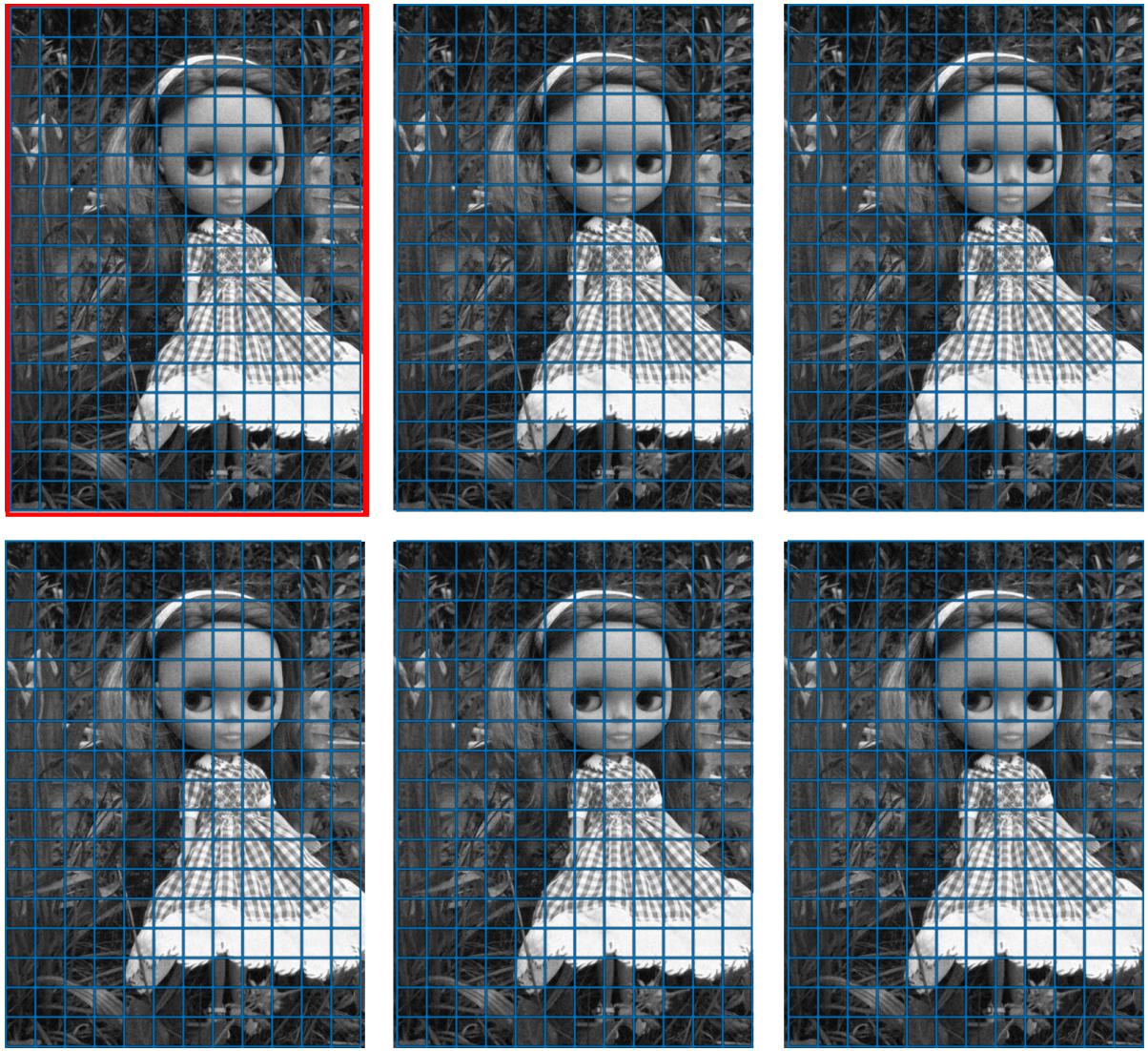
- Take in the input stack of tiled frames
- Denoise the stack using DFTs
- Compare noise intensity to reference frame
- Apply the best tile to the reference
- Implement Pairwise Temporal Filter

Pairwise Temporal Filter

- Let $T_z(\omega)$ be the noise intensity output at z^{th} frame
- Select a tile $\tilde{T}_0(\omega)$ within the reference frame
- Take the average noise intensity in each non-reference tile
- Apply the average to the reference frame

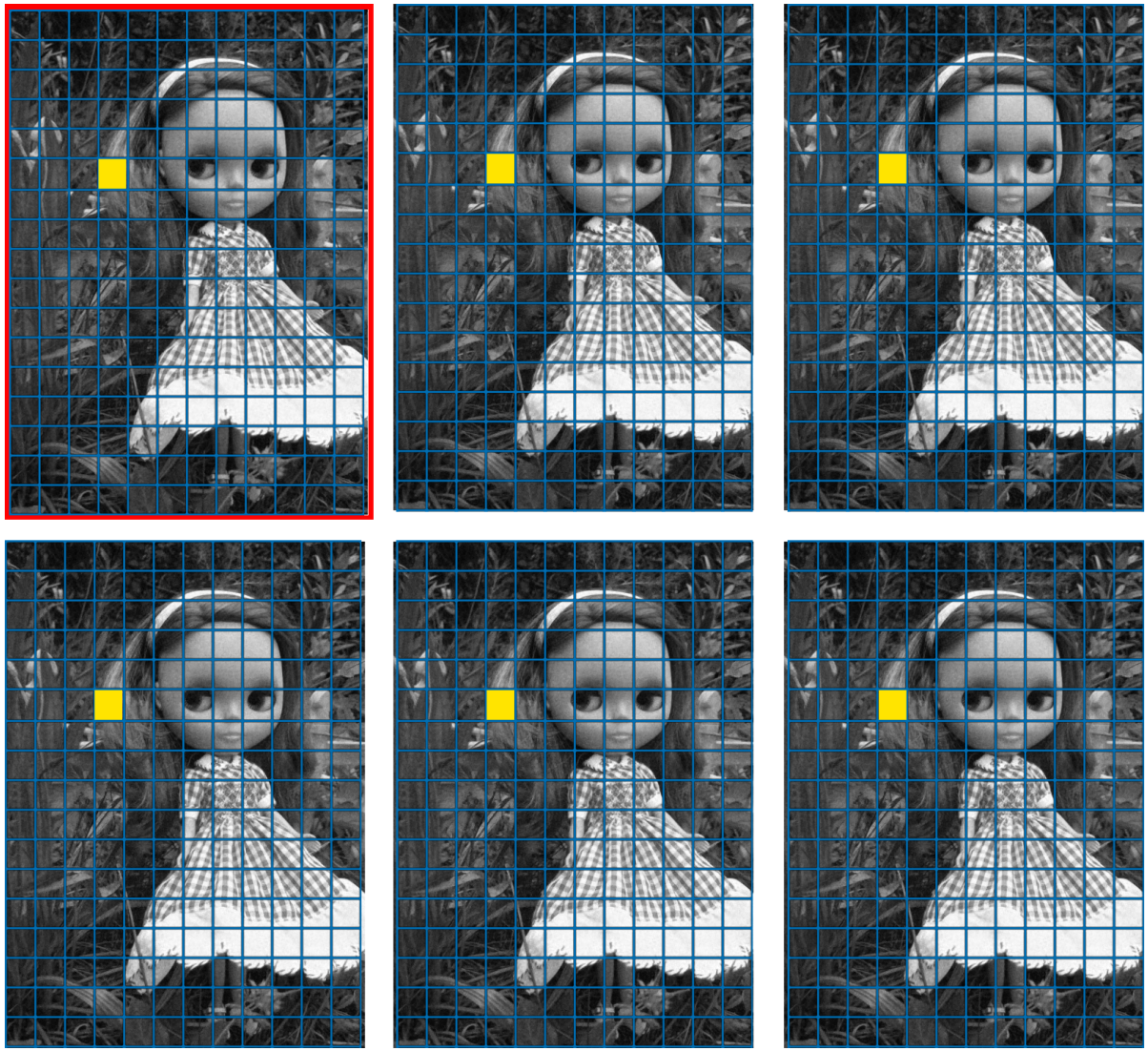
$$\tilde{T}_0(\omega) = \frac{1}{N} \sum_{z=0}^{N-1} \tilde{T}_z(\omega)$$

Burst Merging



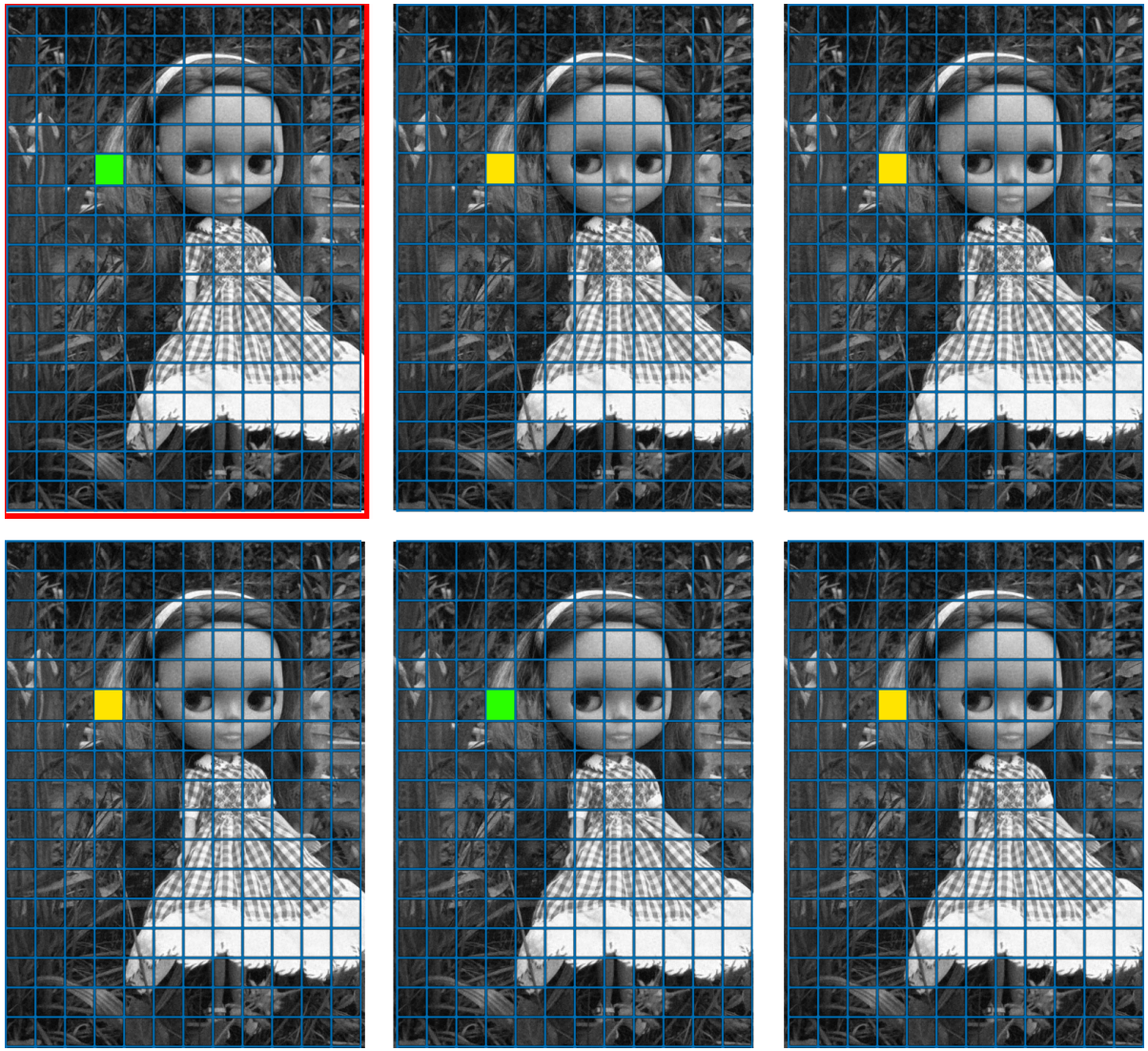
[2]

Burst Merging



[2]

Burst Merging



[2]

Pairwise Temporal Filter (Robustness)

- Account for noise intensity values that don't match the reference tile
- Let $A_z(w)$ control the degree we merge non-reference frame to the reference frame
- Account for alignment failure

$$\tilde{T}_0(\omega) = \frac{1}{N}\sum_{z=0}^{N-1} T_z(\omega) + A_z(\omega)[T_0(\omega) - T_z(\omega)]$$

Burst Merging

[2]

Finishing

- Convert from black & white to full color
- Variety of other adjustments
- Compress to JPEG

[2]

Pixel Fusion

- Developed by Liu et al (2014)
- Microsoft's Fast denoising algorithm
- Temporal Fusion and Multi-scale fusion
- Uses Traditional burst capture
- Uses JPEG instead of RAW

Results

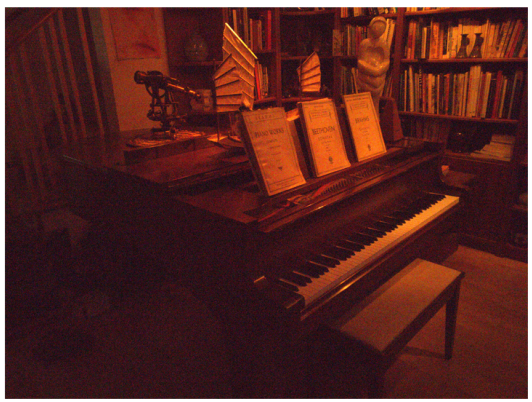
Original

Burst Fusion (Microsoft)

Burst Photography (Google)

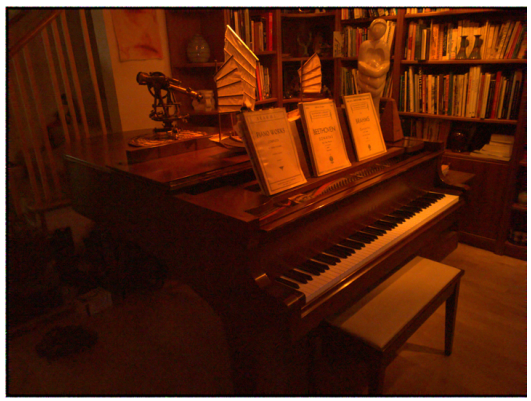
[2]

Results



Original

Burst Fusion (Microsoft)



Burst Photography (Google)

[2]

In Summary

- Burst photography is a recent development for taking high quality photos on a mobile phone.
- Burst photography works well in low-light
- A fresh take on HDR imagining
- A game changer for mobile photography

Questions?

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References

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