Realistic Refocusing

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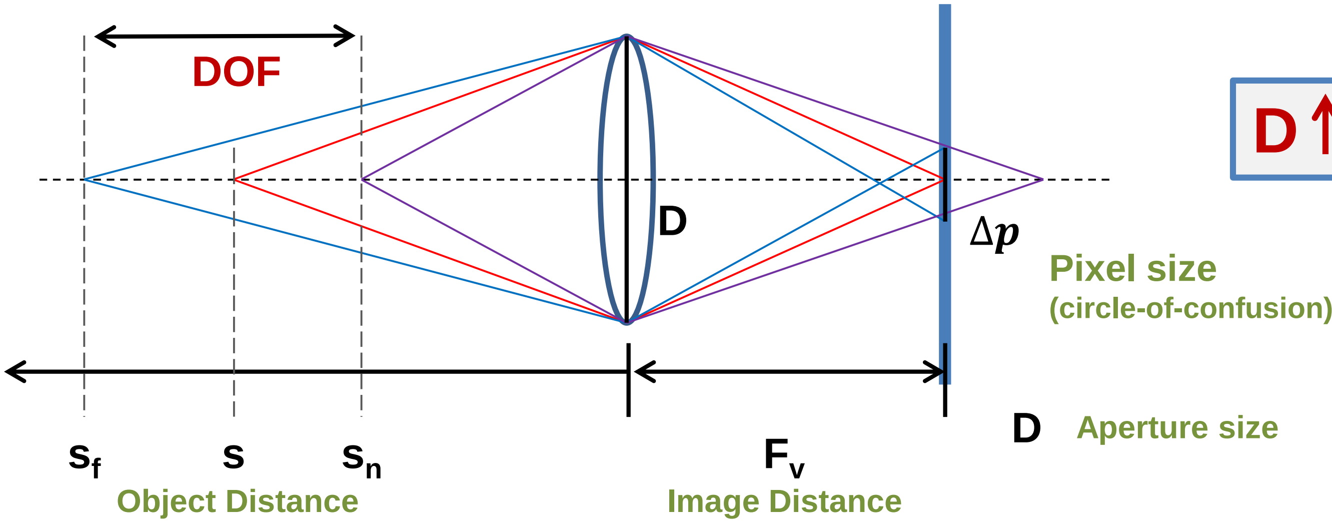
Digital refocusing

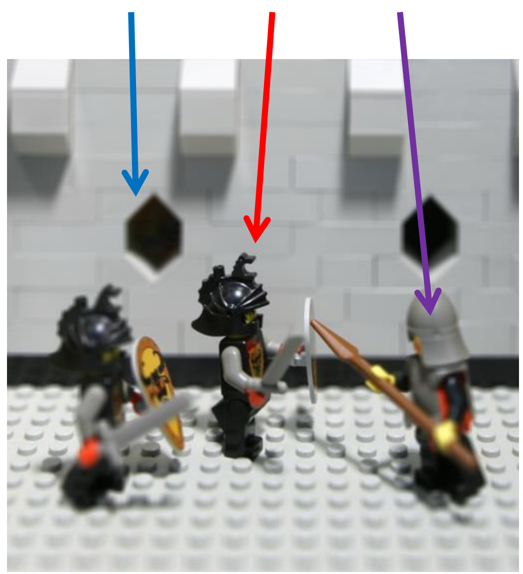
- Provide the depth-of-field effect after capturing pictures
  - Adjustable focal plane, aperture size, aperture shape, …

More pictures on https://pictures.lytro.com/

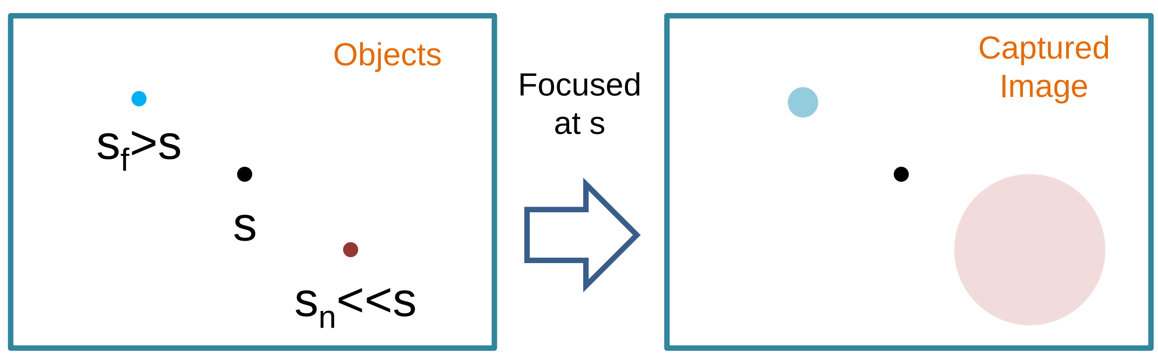
Ref: http://www.ee.nthu.edu.tw/chaotsung/sparse_lf_refocus/
http://web.ee.nthu.edu.tw/files/14-1030-79438,r2471-1.php

Depth of field (DOF)





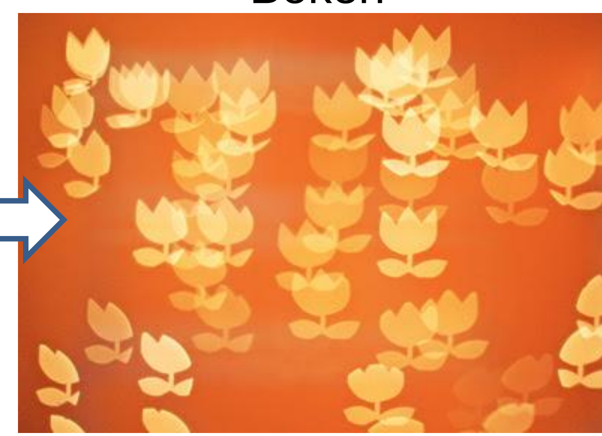
D↑ ⇒ DOF↓



DOF effect

[source: Nikon sample movie]

Bokeh



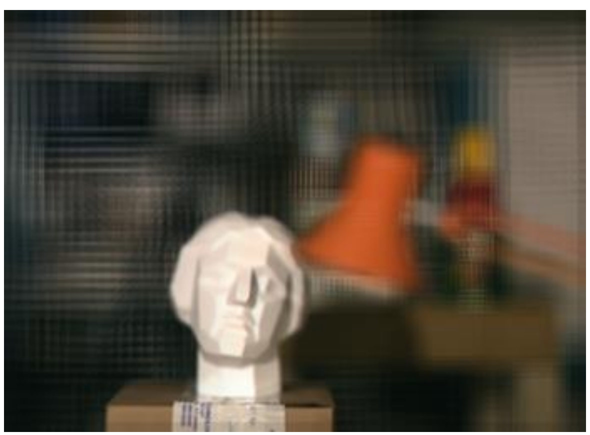
Ref: http://howaboutorange.blogspot.tw/2011/05/photography-diy-how-to-make-your-own.html

Computation and artifact

- Basic operation: Shift and average (CGL)
  - Shift by disparities for each view
  - Average all shifted views as the refocused image

Hands-on webpage http://lightfield.stanford.edu/lfs.html

- Major artifact: Aliasing effect
  - Due to insufficient view sampling



Post-processing

Outline

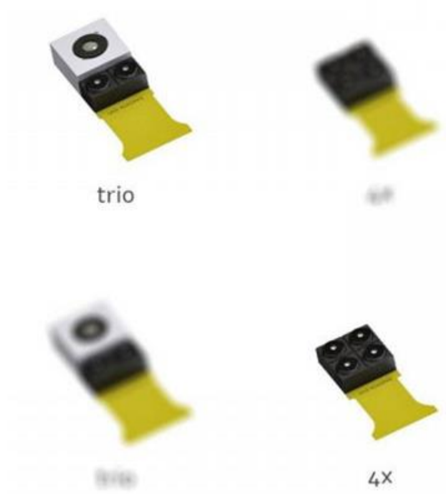
- Conventional refocusing methods
  – View interpolation for sparse light fields
  – Image blurring for single-view images

- Fast realistic refocusing for sparse light fields

Sparse light field

- Sparse view sampling
  - Large disparity between neighboring views
  - Typical hardware configuration: Camera array
    - Few views, large baseline (lower storage/higher resolution)
  - Examples:

Pelican Imaging



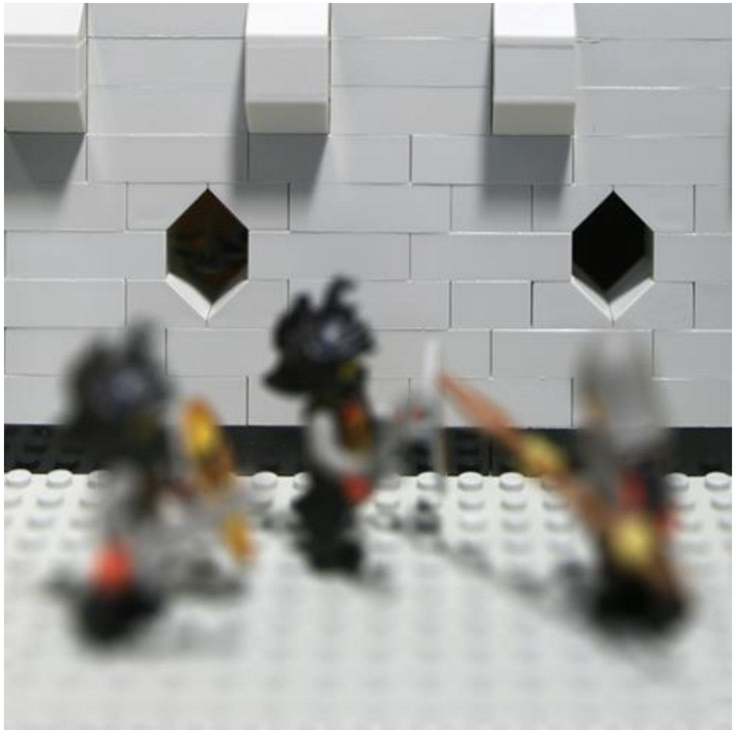
LinX
(acquired by Google)

Light

View-interpolation-based refocusing

- Great quality by explicitly handling occlusion
- Complexity $O(C_{vi} \times \text{view number} \times \text{resolution})$
  - C_{vi}: complexity of view interpolation algorithm, e.g. morphing or high-quality view synthesis.

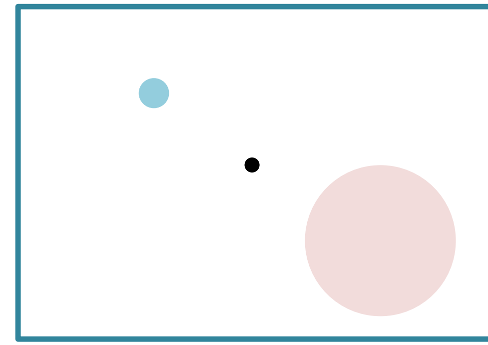
Direct shift-and-add



Interpolate 441(knight)/797(BG) views

Simplest refocusing: Single-image blurring

- Most popular so far for its efficiency
- Work for single-image systems
    - e.g. HTC M8, Google Camera
- Blur kernel radius $\propto |\Delta d|$



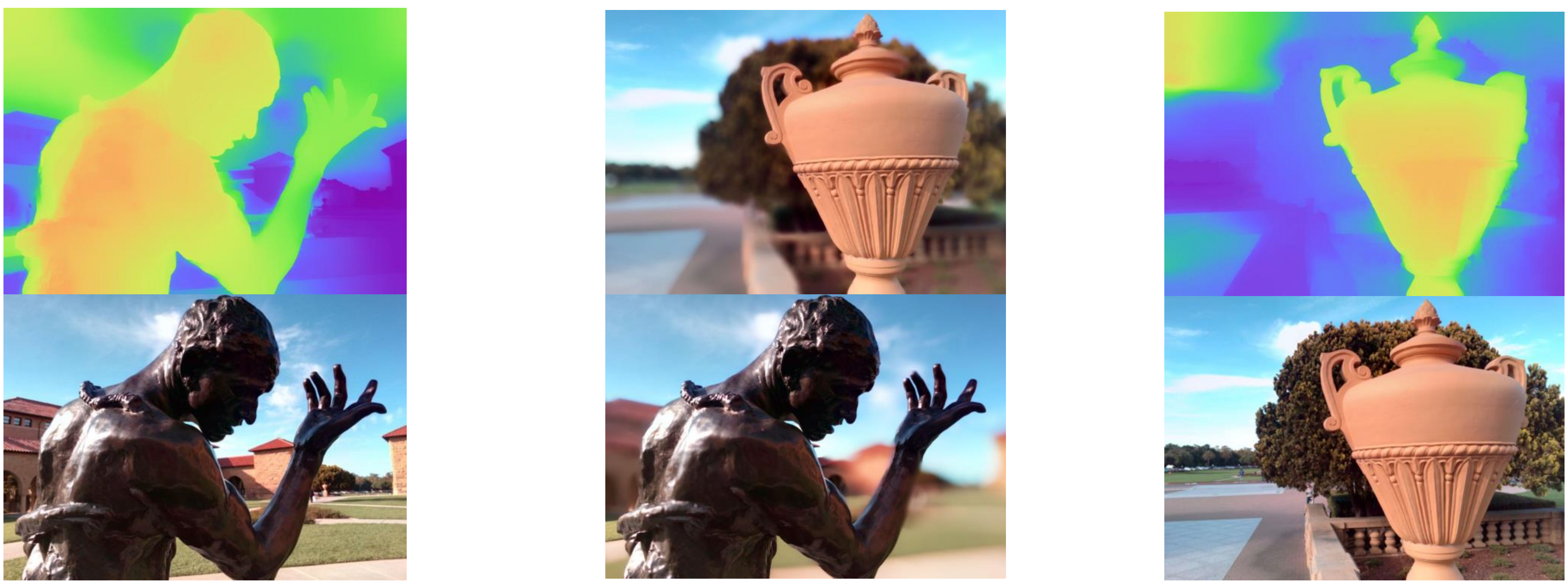
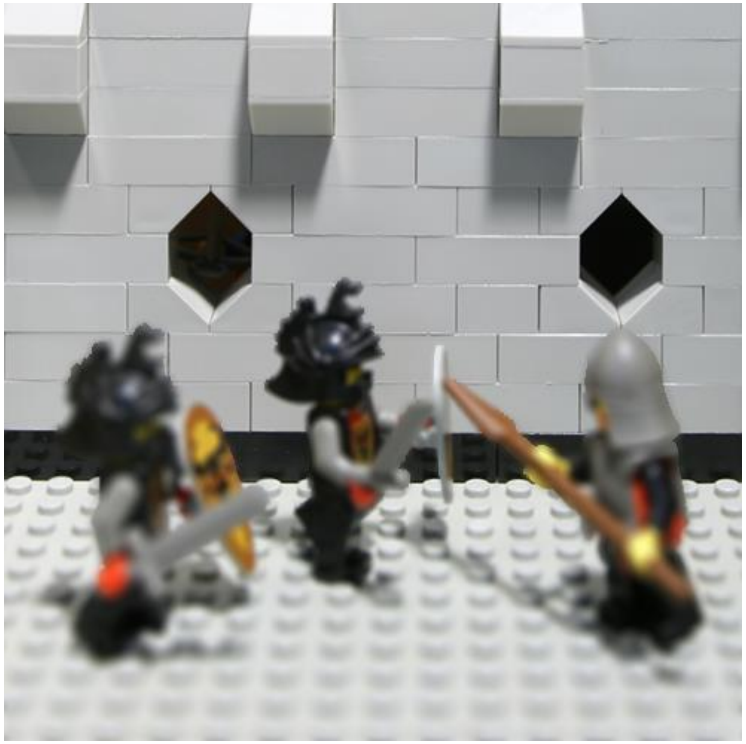


Fig : J. Barron, et. al., "Fast bilateral-space stereo for synthetic defocus," CVPR'15 (supple.).

Boundary issues

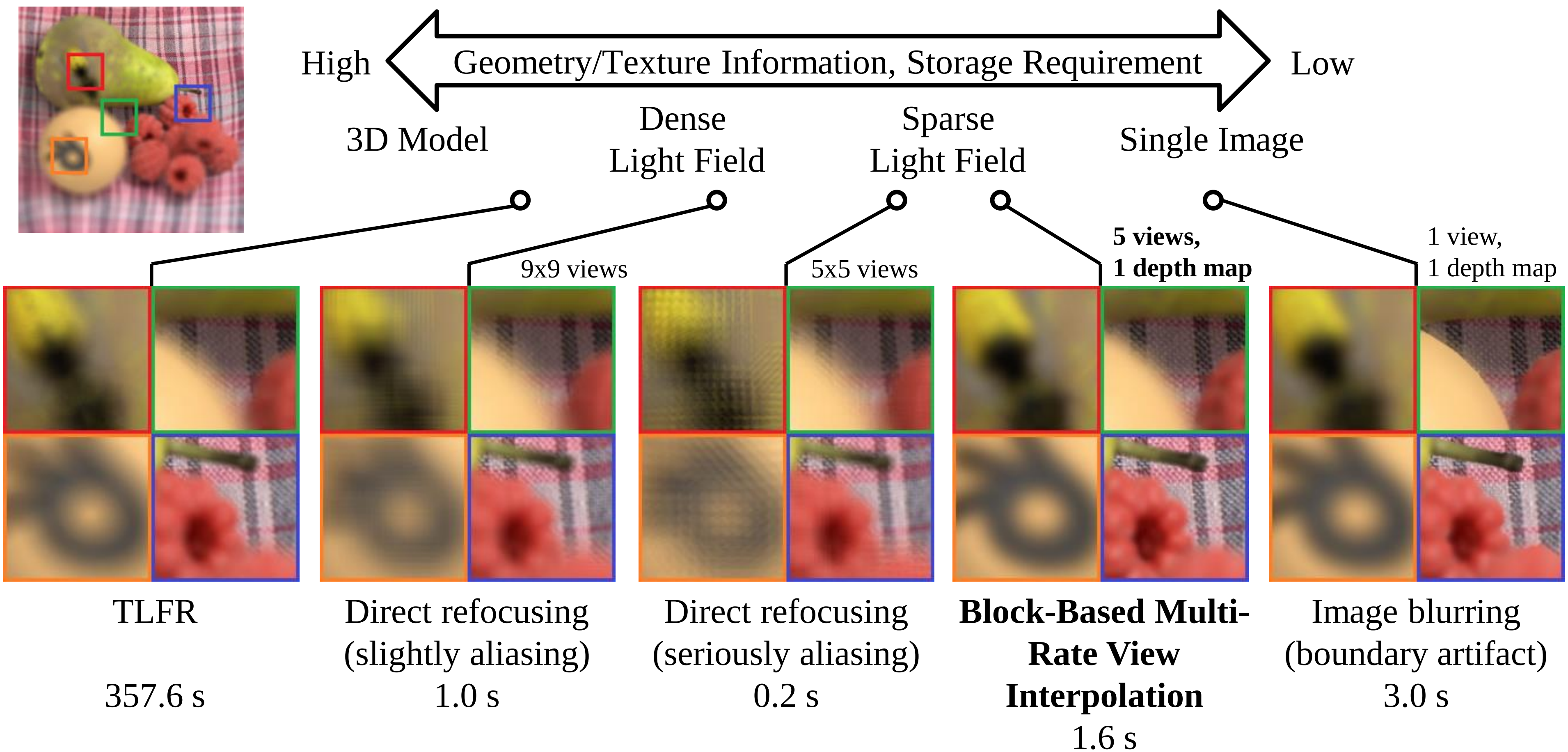
- Especially for large-aperture refocusing at background



Outline

- Conventional refocusing methods
  - View interpolation for sparse light fields
  - Image blurring for single-view images
- **Fast realistic refocusing for sparse light fields**

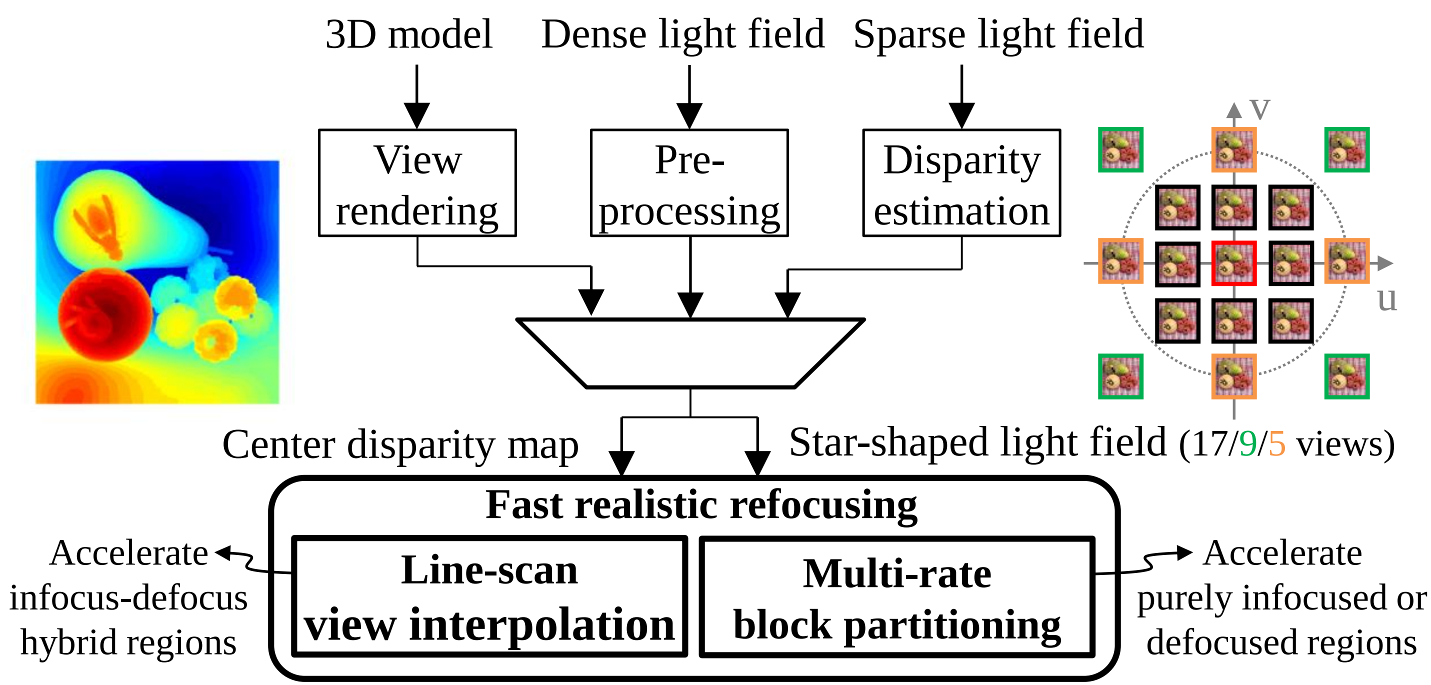
Tradeoff of refocusing



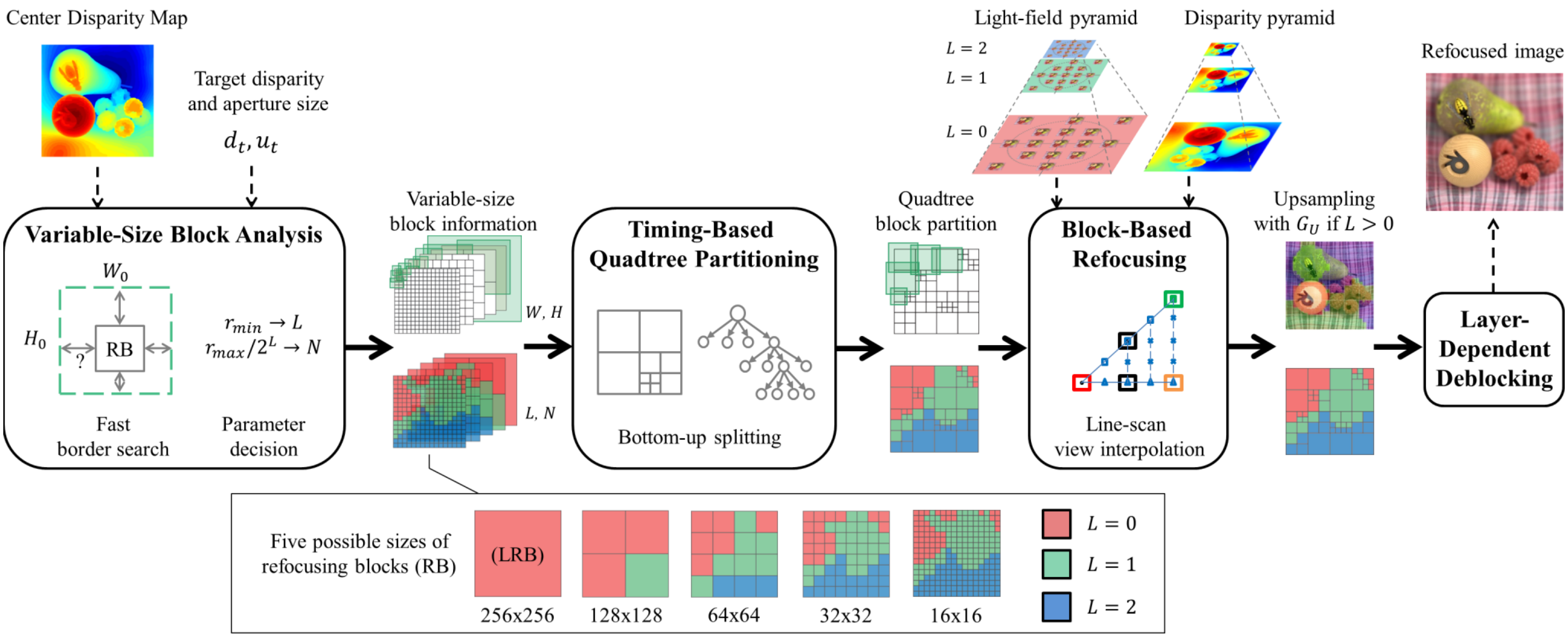
Ref: C.-T. Huang, et. al., "Fast Realistic Refocusing for Sparse Light Fields Using Block-Based Multi-Rate View Interpolation," paper draft.

Proposed system

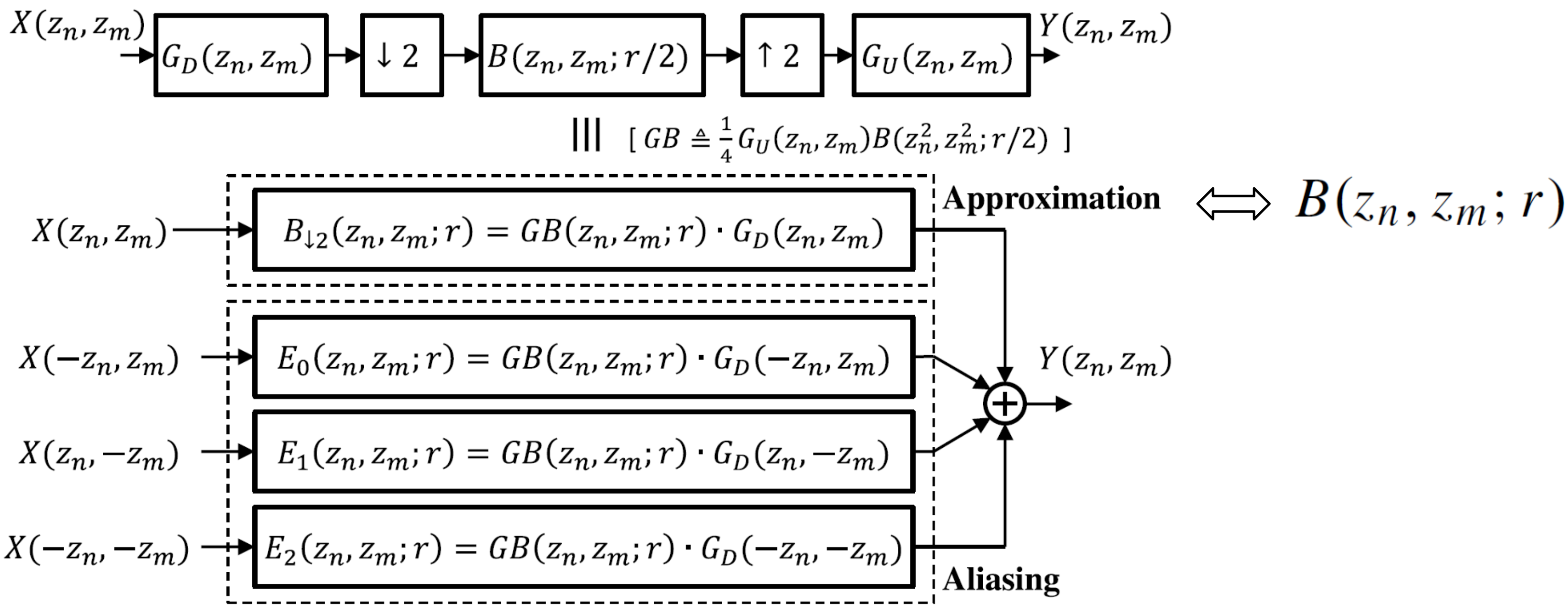
- High-speed and high-quality refocusing with few views
- Ideas for areas of different characteristics
  - Infocused: less view interpolation is required => block-based flow
  - Defocused: refocused at subsampled domain => multi-rate mode
  - Hybrid*: fast view interpolation to handle occlusion



System flow of
block-based multi-rate view interpolation



Rule of subsample-by-two refocusing



Blur radius r	β_D	θ	Approx. error $SSE_{\downarrow 2}$	Aliasing energy SSE_a
2.0	0.00	0.19π	4.3×10^{-3}	1.4×10^{-3}
2.5	0.61	0.26π	1.6×10^{-3}	7.4×10^{-4}
3.0	**1.28**	**0.26π**	**6.7×10^{-4}**	**1.4×10^{-4}**
3.5	1.44	0.27π	3.0×10^{-4}	5.3×10^{-5}
4.0	1.49	0.28π	1.3×10^{-4}	3.0×10^{-5}

$$L = \begin{cases} 2, & r_{min}/2 \geq 3 \\ 1, & 3 \leq r_{min} < 6 \\ 0, & \text{otherwise} \end{cases}$$

Subjective quality comparison

TLFR

Block-based, SSLF-17

Block-based, SSLF-5

Image blurring

GF2, 18-mm, f/4.3 (FG)

Block-based, $u_t = 0.43$ (FG)

GF2, 18-mm, f/4.3 (BG)

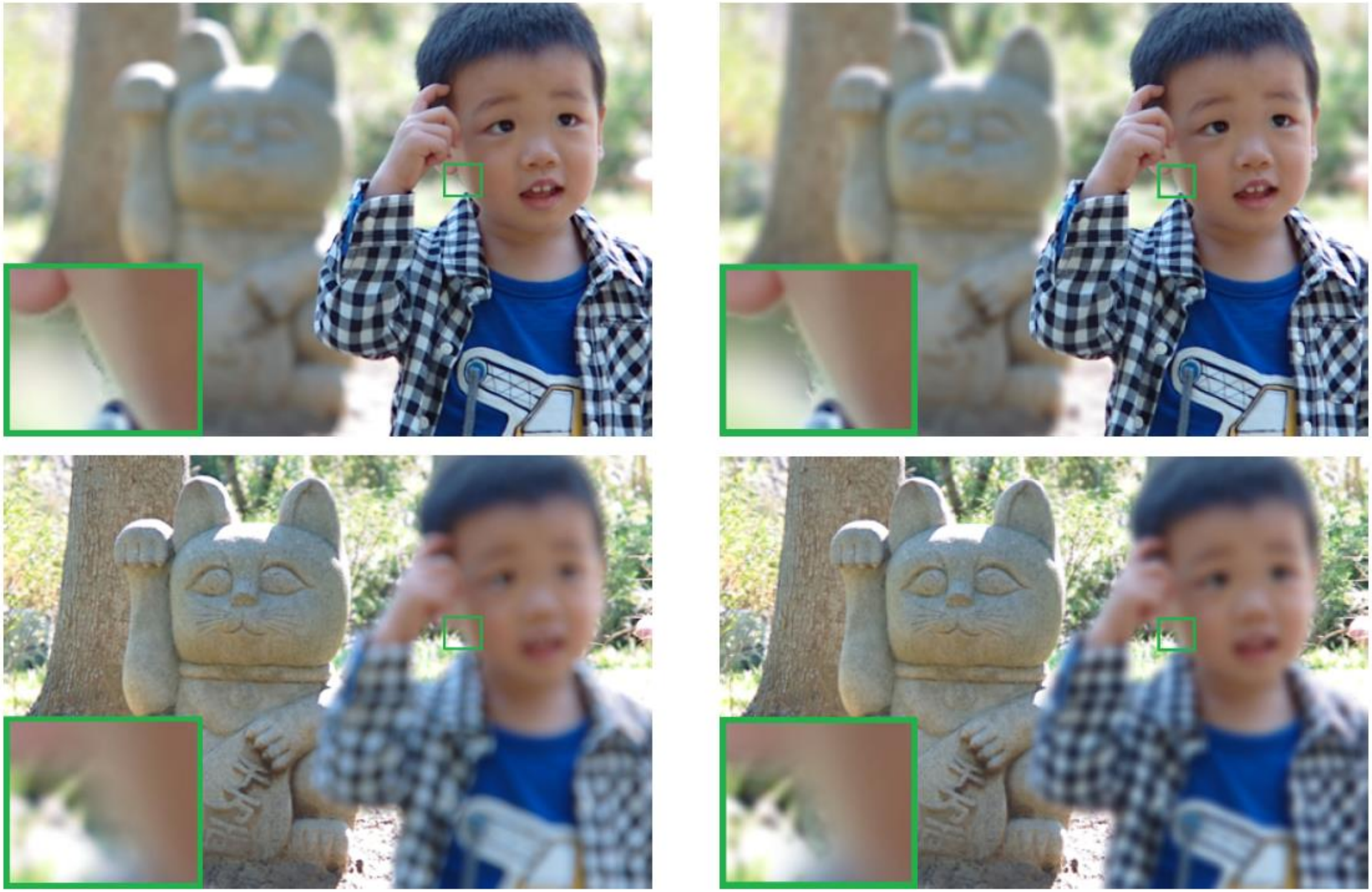
Block-based, $u_t = 0.43$ (BG)

Subjective quality comparison

Lytro Desktop, f/2

Block-based, $u_t = 1$

Subjective quality comparison



Lytro Desktop, f/2 Block-based, $u_t = 1$

Speed comparison

Scene-dependent performance; could be faster than blurring (due to multi-rate modes)