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V-SENSE

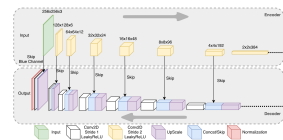
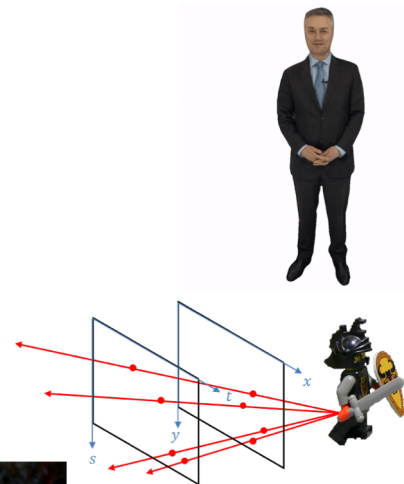
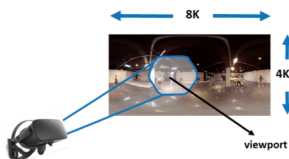
Light field research challenges

Dr Martin Alain, Dr Mikael Le Pendu, Dr Weston Aenchbacher, Yang Chen, Dr Mairead Grogan,
Pierre Matysiak, Prof Aljosa Smolic
alainm@scss.tcd.ie

VSENSE

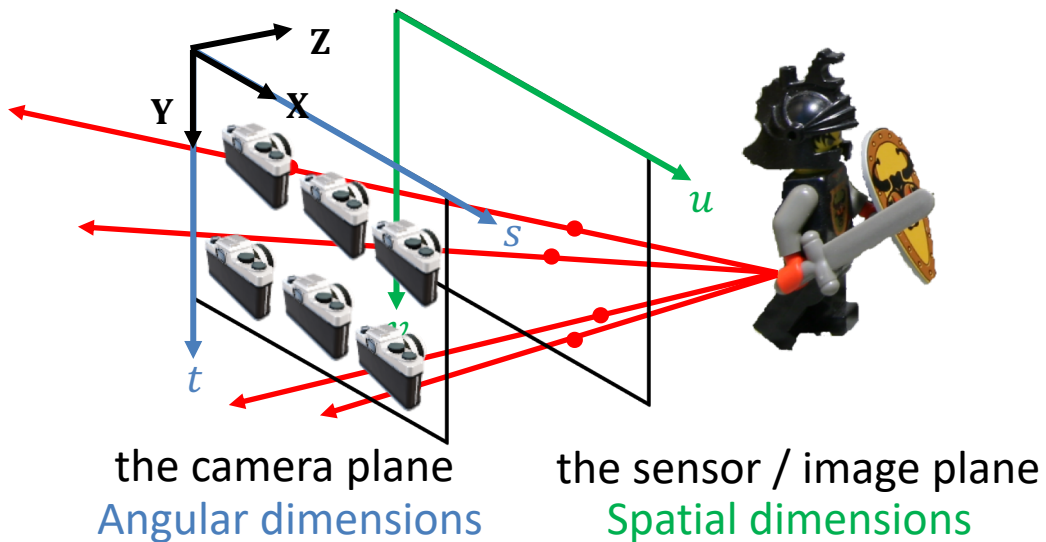
Extending Visual Sensation through Image-Based Visual Computing

- **6DoF – AR/VR & Free Viewpoint Video**
- **3DoF – 360 VR Video**
- **Light Field Imaging**
- **Visual Effects & Animation**
- **Deep Learning for Visual Computing**
- **Creative Experiments**

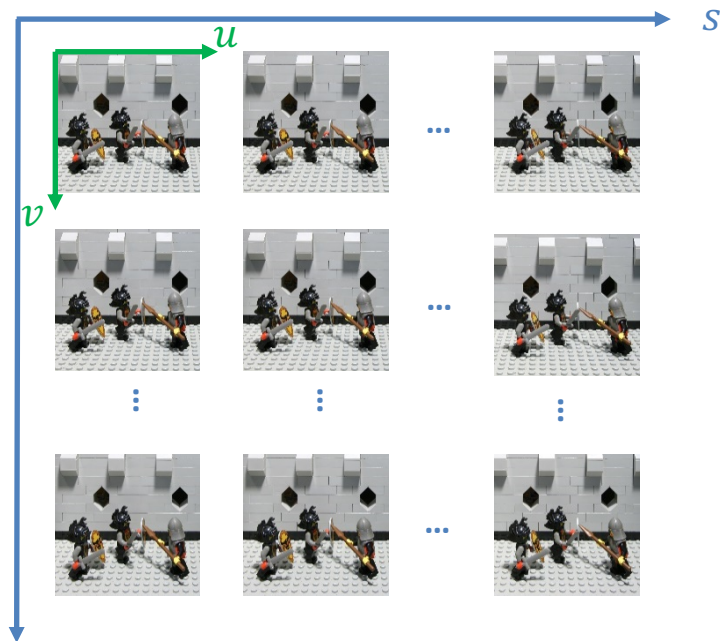


Light field imaging

2 parallel planes parameterization



The light field $L = L(s, t, u, v)$



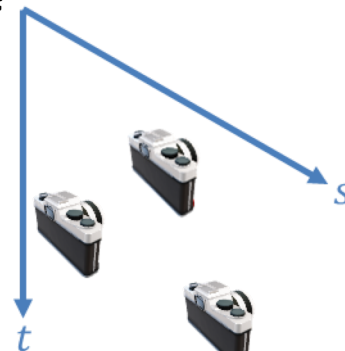
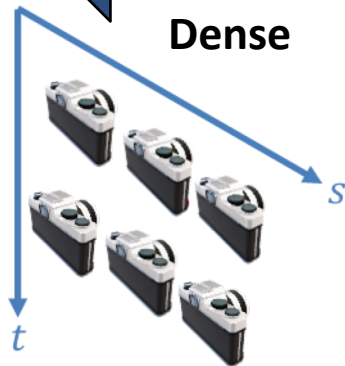
The light field spectrum

Angular sampling

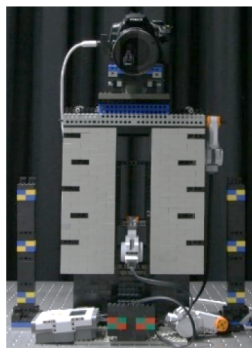


Dense

Sparse



Handheld
plenoptic camera



Single camera
+ gantry



Camera array



The light field spectrum

Angular sampling

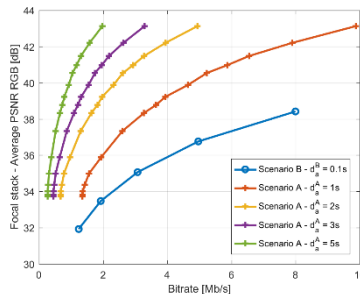


The light field spectrum

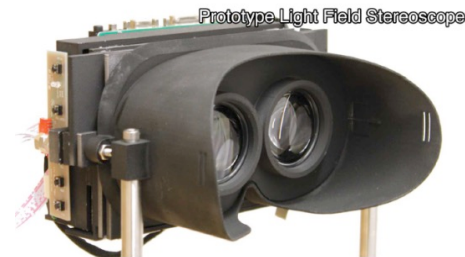
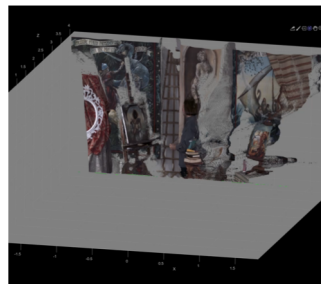
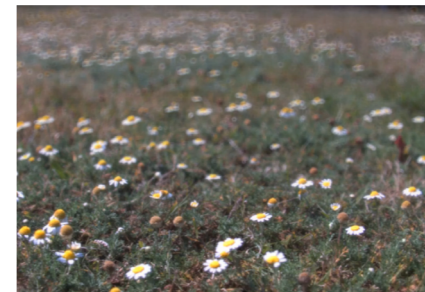
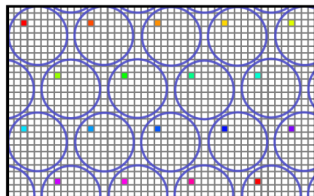
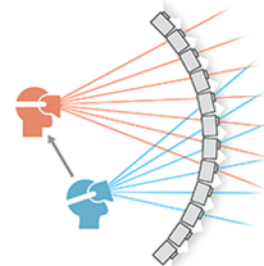
Light field processing and applications



Low level

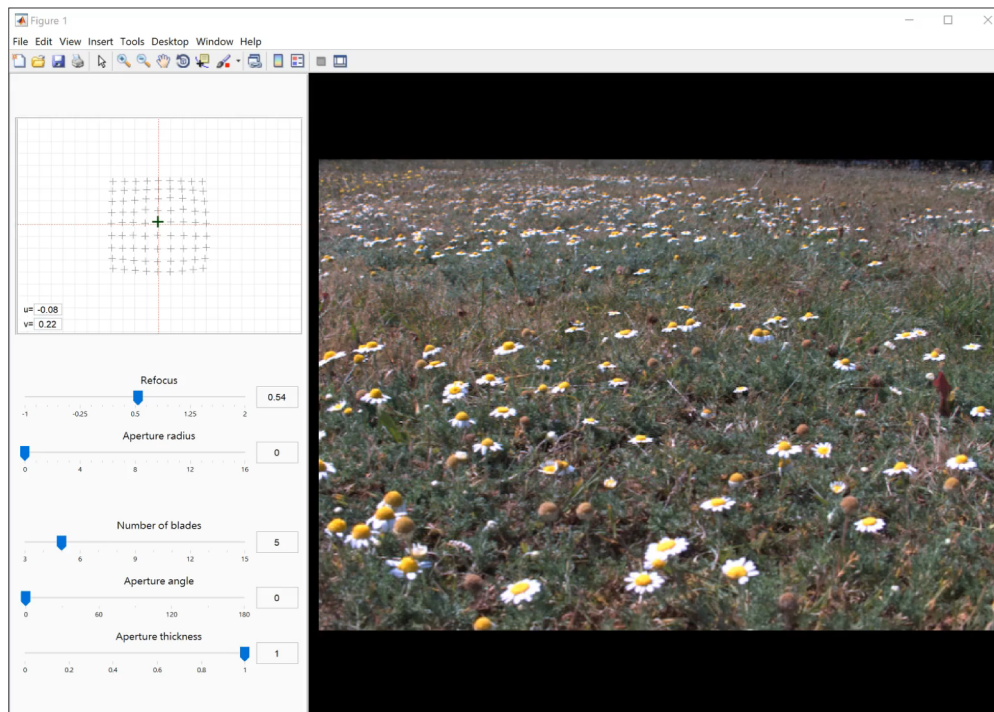


High level



Application example

Refocusing

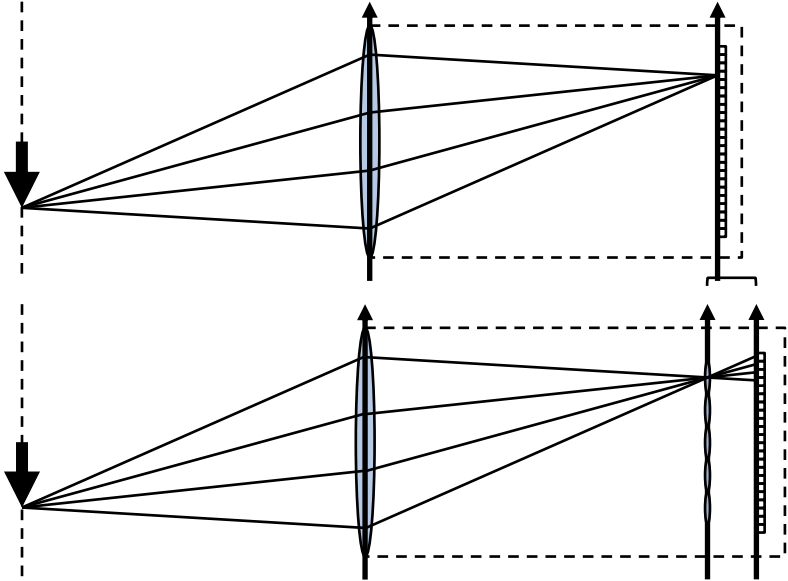


**“A Fourier Disparity Layer representation for Light Fields”,
M. Le Pendu; C. Guillemot; Aljosa Smolic; IEEE Transactions on Image Processing 2019**

Dense light field processing



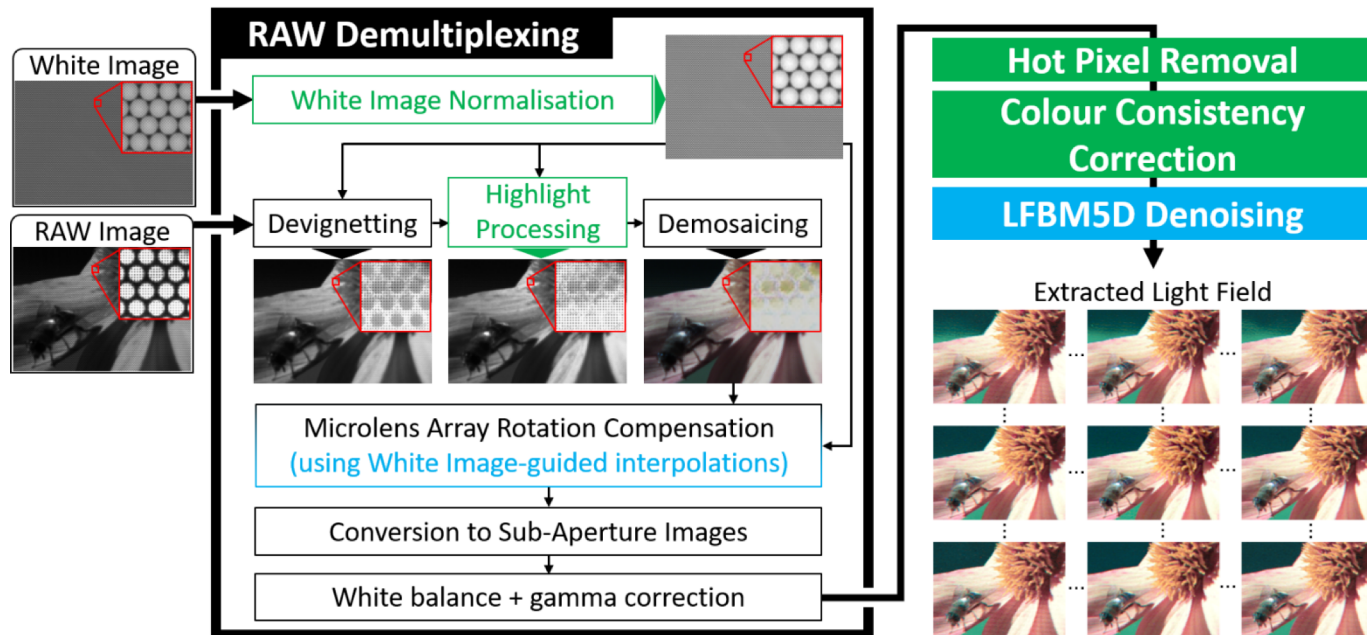
Lytro Illum
Handheld
plenoptic camera



Credit: Weston Aenchbacher



Dense light field processing



“A Pipeline for Lenslet Light Field Quality Enhancement”,

Pierre Matysiak ; Mairead Grogan ; Mikael Le Pendu ; Martin Alain ; Aljosa Smolic; ICIP 2018

Dense light field processing

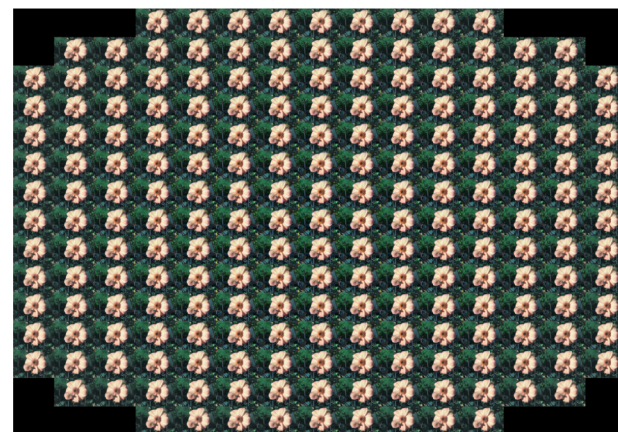
Colour correction



Dansereau's Matlab toolbox



RAW Decoding



+ Colour consistency

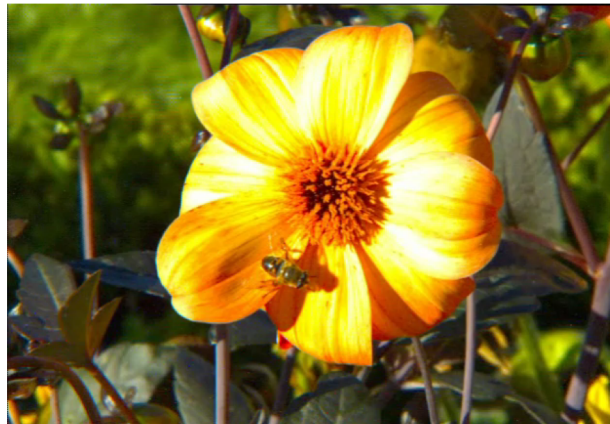
"A Pipeline for Lenslet Light Field Quality Enhancement",

Pierre Matysiak ; Mairead Grogan ; Mikael Le Pendu ; Martin Alain ; Aljosa Smolic; ICIP 2018

Dense light field processing

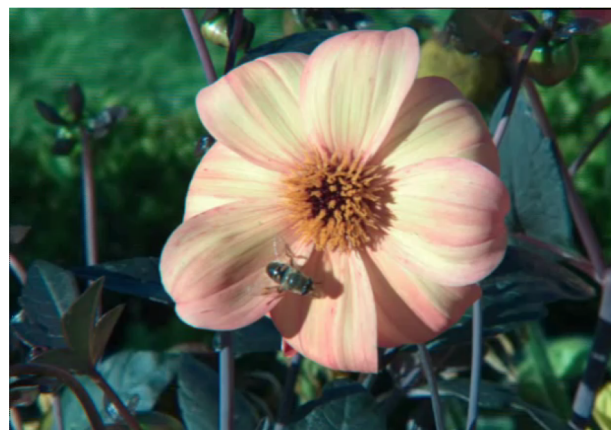
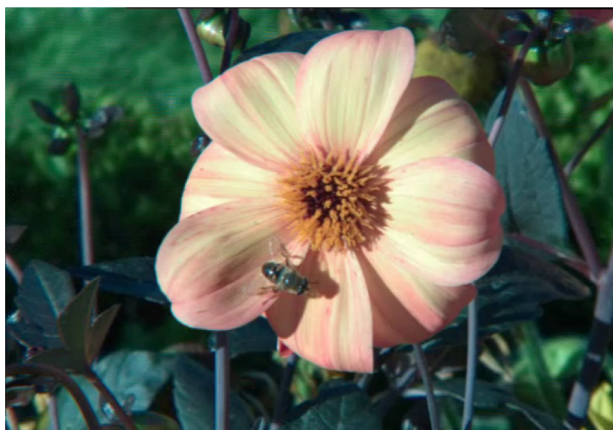
Full pipeline

Dansereau's
Matlab toolbox



RAW
Decoding

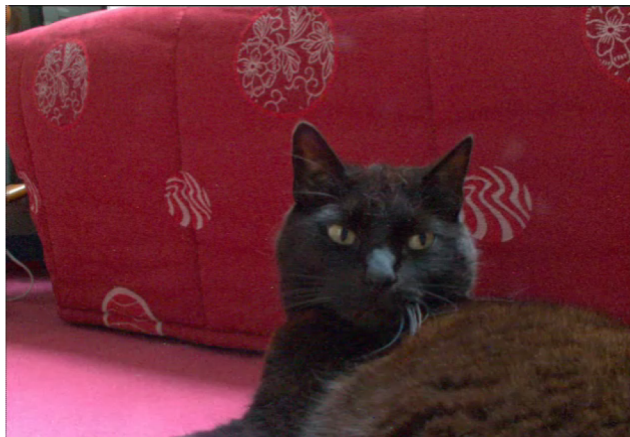
+ Colour
consistency



+ Denoising

Dense light field processing

Full pipeline



RAW Decoding



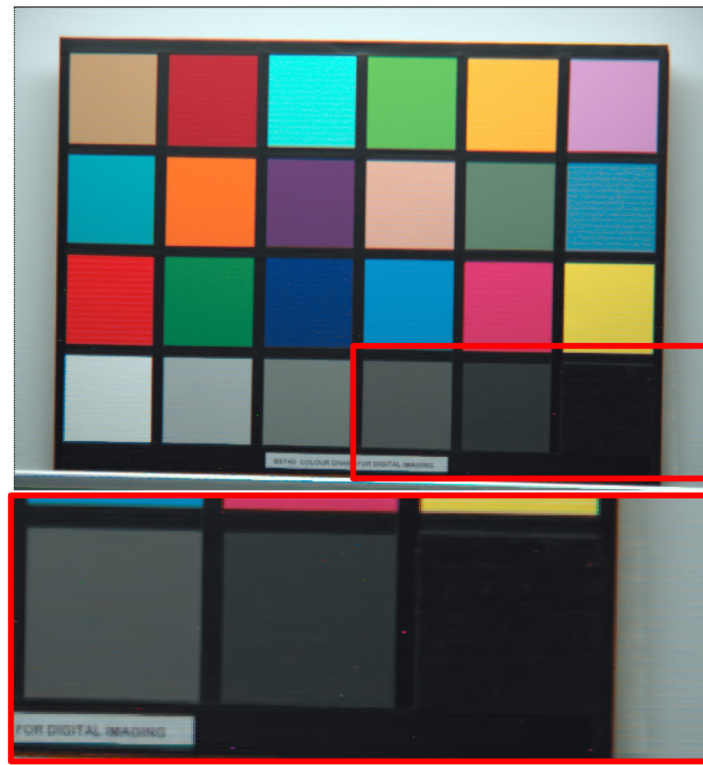
+ Colour consistency



+ Denoising

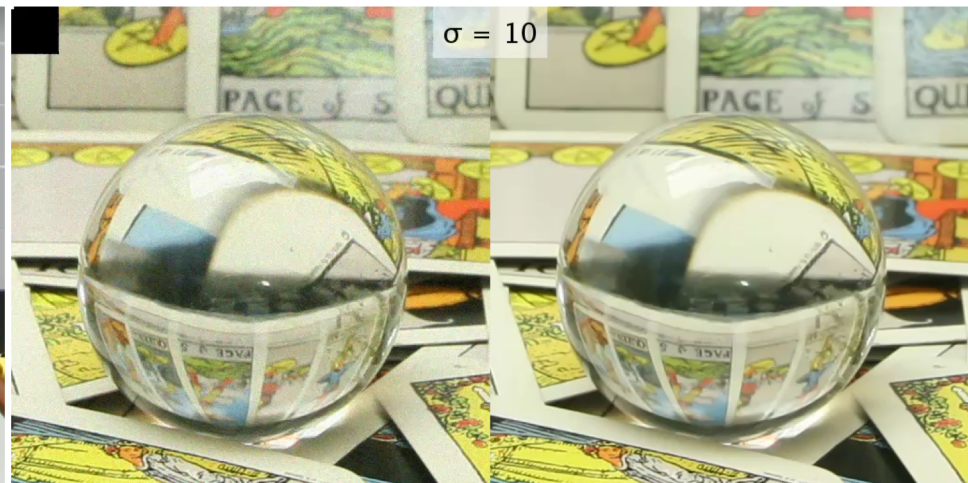
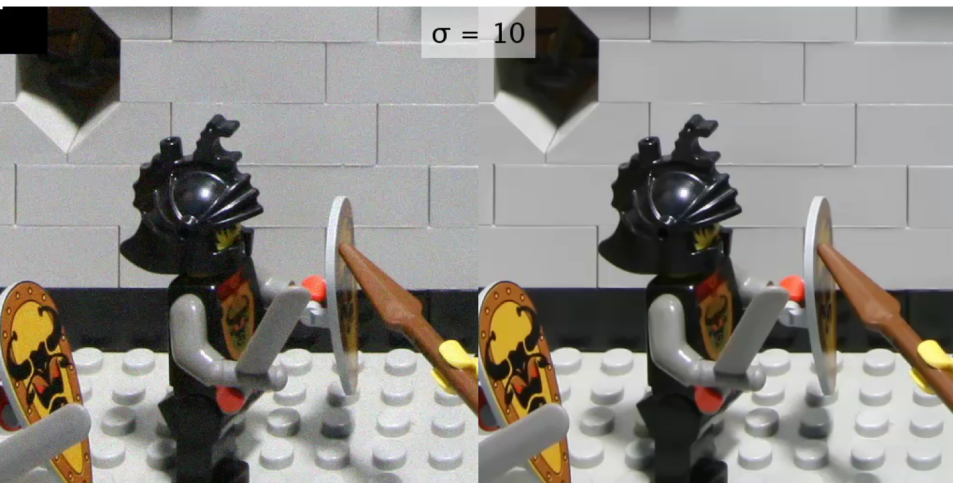
Dense light field processing

Denoising



Dense light field processing

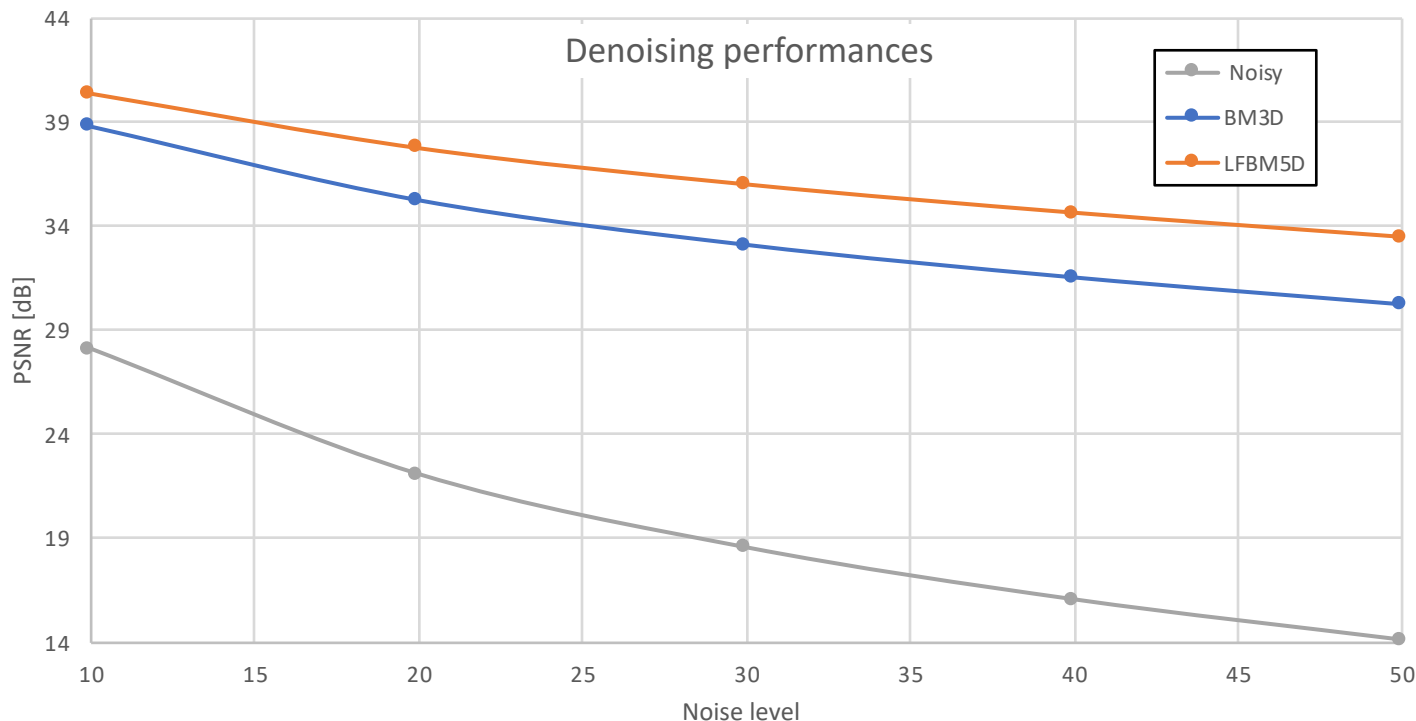
Denoising



“Light field denoising by sparse 5D transform domain collaborative filtering”, M. Alain, A. Smolic; MMSP 2017

Dense light field processing

Comparison to single image processing



Over 2dB gain
in average

“Light field denoising by sparse 5D transform domain collaborative filtering”, M. Alain, A. Smolic; MMSP 2017

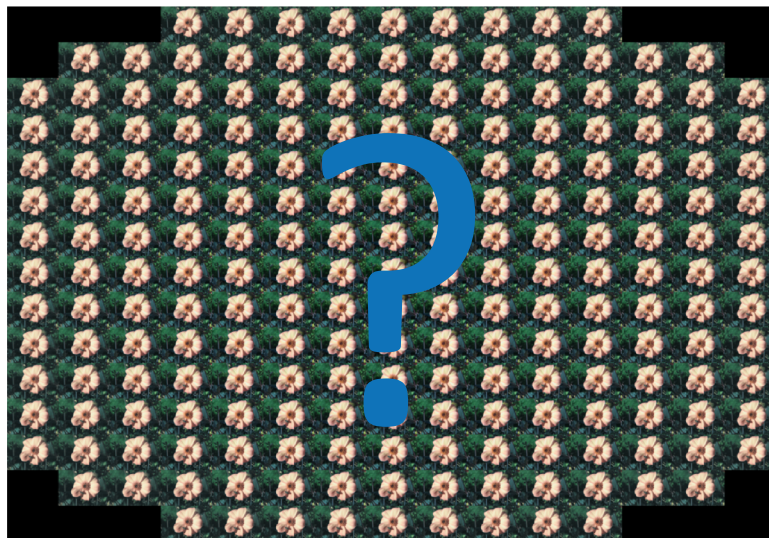
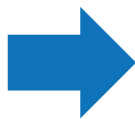
Dense light field processing

Super-resolution

$$L_H^* = \operatorname{argmin}_{L_H} \|L_L - D_\alpha L_H\|_2^2 \quad \text{Ill-posed}$$



$$L_L = D_\alpha L_H$$



L_H

“Light Field Super-Resolution via LFBM5D Sparse Coding”, M. Alain, A. Smolic; ICIP 2018

Dense light field processing

Super-resolution



Bicubic



Super-resolution

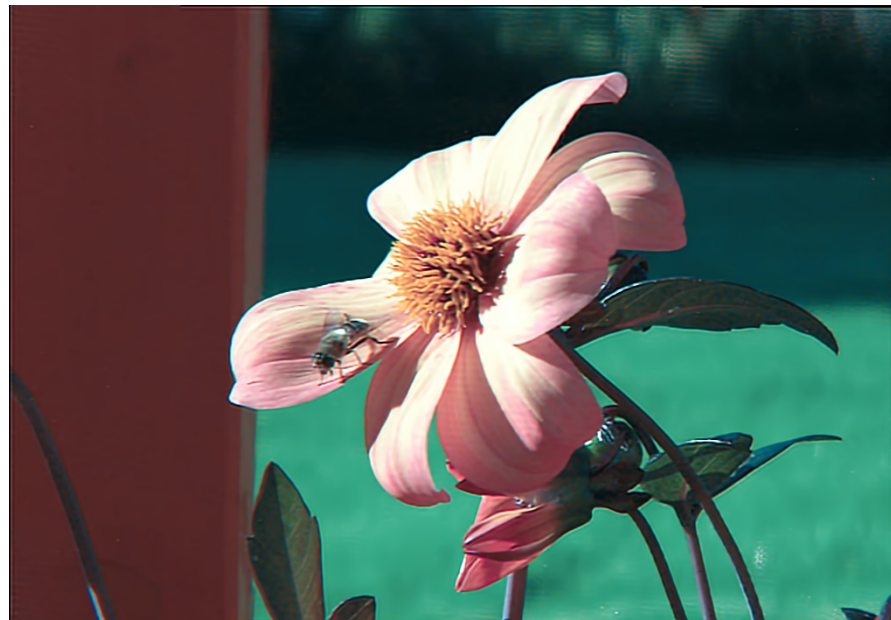
“Light Field Super-Resolution via LFBM5D Sparse Coding”, M. Alain, A. Smolic; ICIP 2018

Dense light field processing

Super-resolution



Bicubic



Super-resolution

“Light Field Super-Resolution via LFBM5D Sparse Coding”, M. Alain, A. Smolic; ICIP 2018

Dense light field processing

Super-resolution



Bicubic

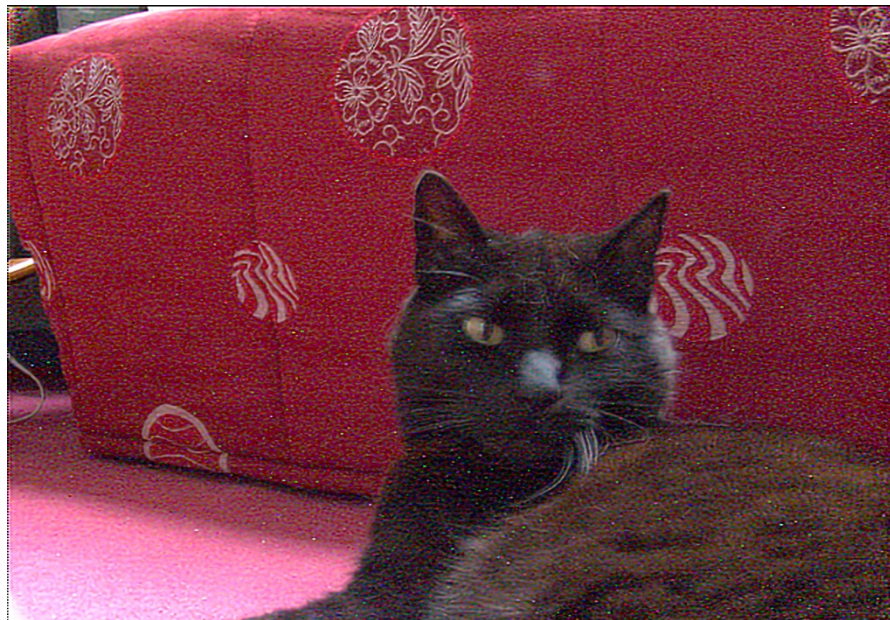


Super-resolution

“Light Field Super-Resolution via LFBM5D Sparse Coding”, M. Alain, A. Smolic; ICIP 2018

Dense light field processing

Super-resolution



Dansereau



Full pipeline

“Light Field Super-Resolution via LFBM5D Sparse Coding”, M. Alain, A. Smolic; ICIP 2018

Dense light field processing

Super-resolution



Bicubic

Super-resolution

“Light Field Super-Resolution via LFBM5D Sparse Coding”, M. Alain, A. Smolic; ICIP 2018

Dense light field processing

Super-resolution



Bicubic

Super-resolution

“Light Field Super-Resolution via LFBM5D Sparse Coding”, M. Alain, A. Smolic; ICIP 2018

Dense light field processing

Comparison to single image processing



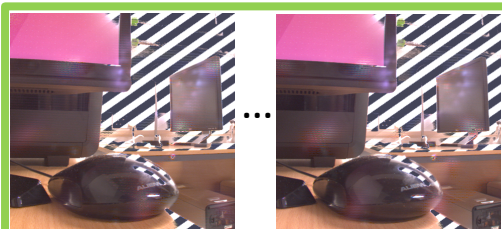
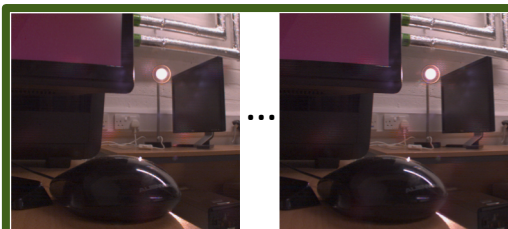
0.7dB gain
in average

Dense light field processing

High dynamic range

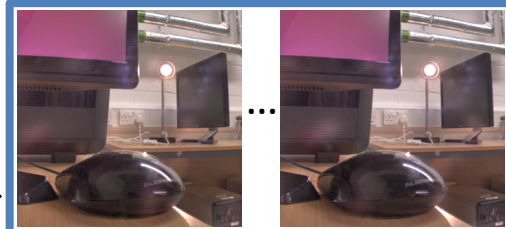


Soft saturation detection + RAW De-multiplexing



Weighted
Low Rank
Approximation

HDR Light Field
(keeping only the recovered
high exposure)



“High Dynamic Range Light Fields via Weighted Low Rank Approximation”,
M. Le Pendu, C. Guillemot, A. Smolic; ICIP 2018

Dense light field processing

High dynamic range



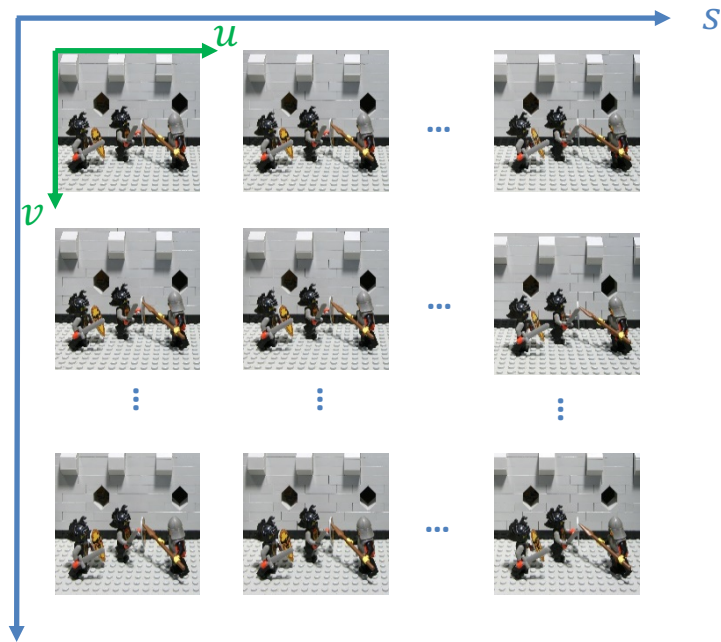
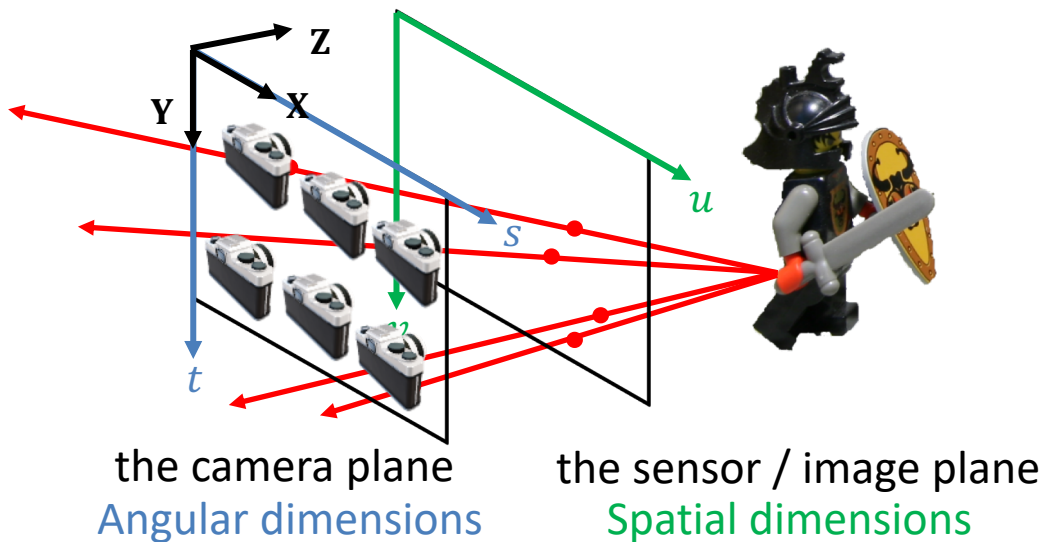
HDR Light Field



**“High Dynamic Range Light Fields via Weighted Low Rank Approximation”,
M. Le Pendu, C. Guillemot, A. Smolic; ICIP 2018**

Dense vs sparse light field processing

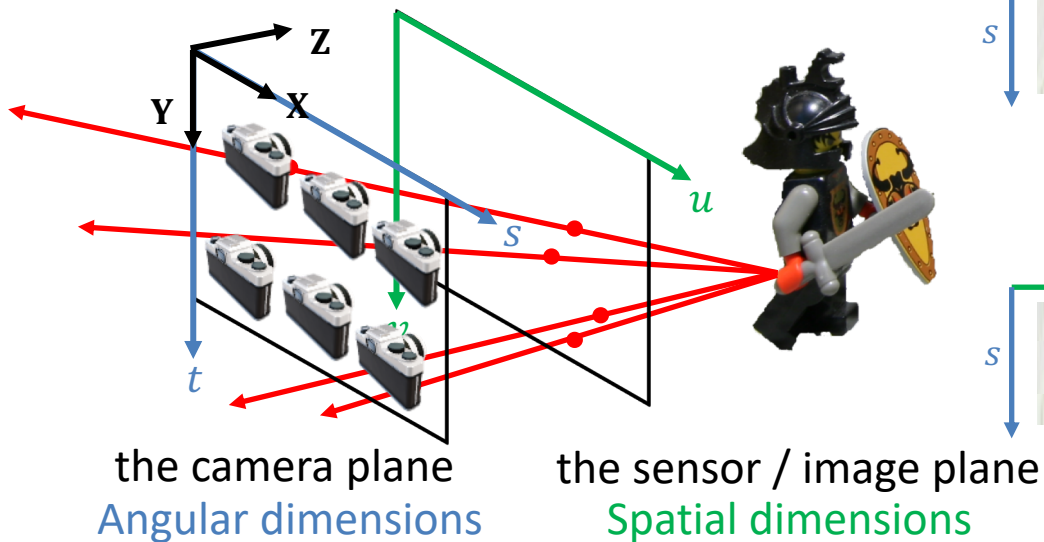
Depth estimation



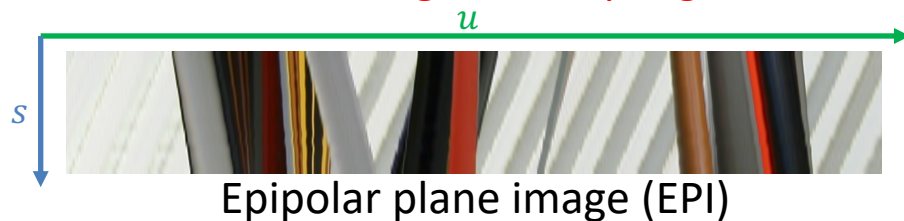
$$\text{The light field } L = L(s, t, u, v)$$

Dense vs sparse light field processing

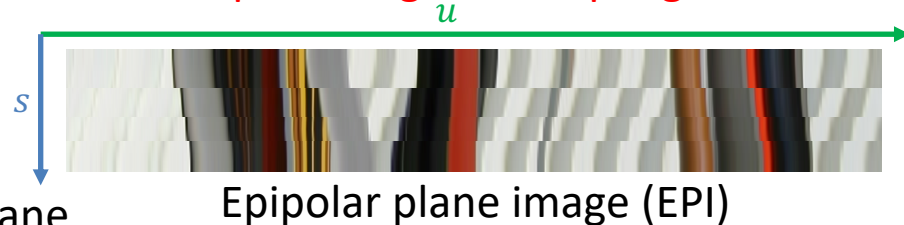
Depth estimation



Dense angular sampling



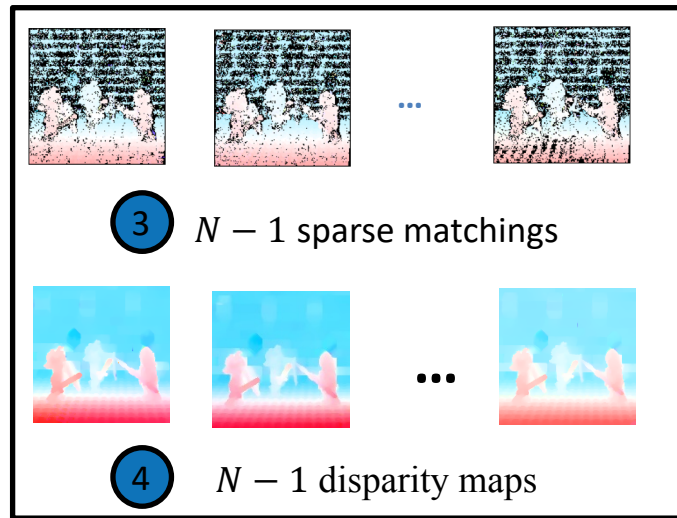
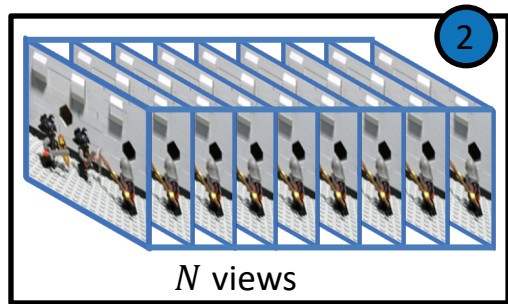
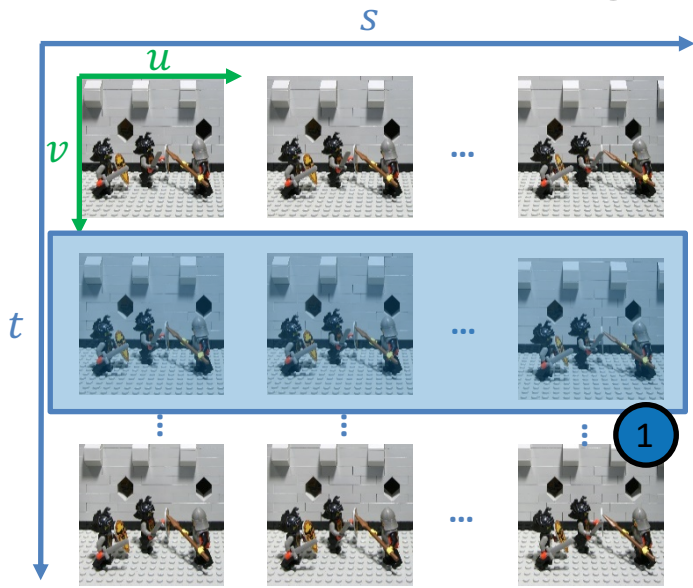
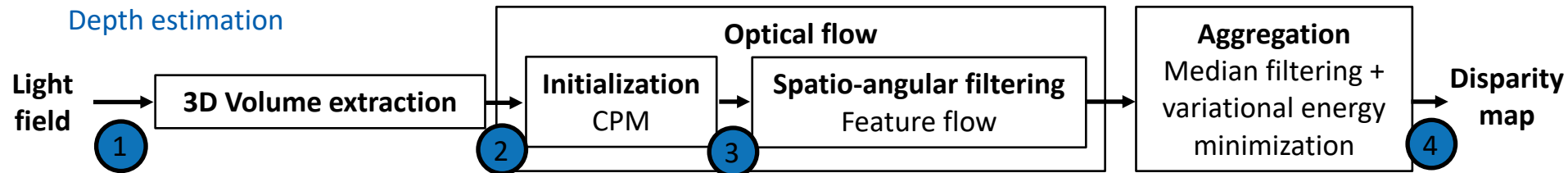
Sparse angular sampling



$$\text{The light field } L = L(s, t, u, v)$$

Sparse light field processing

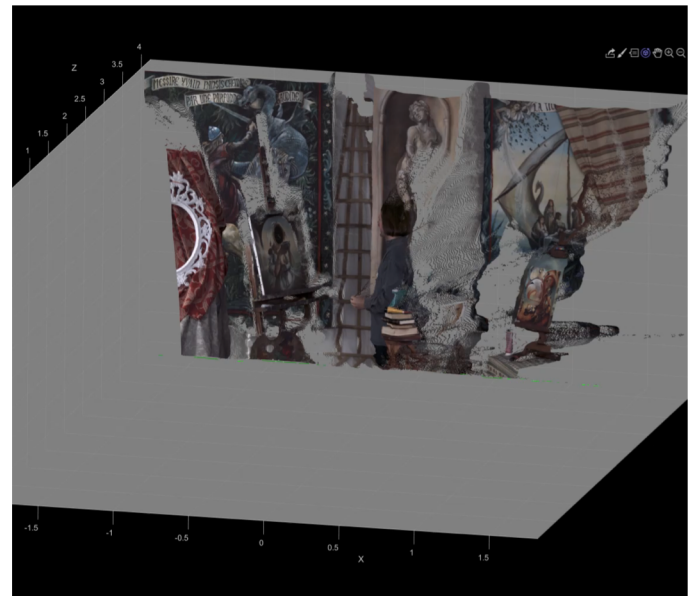
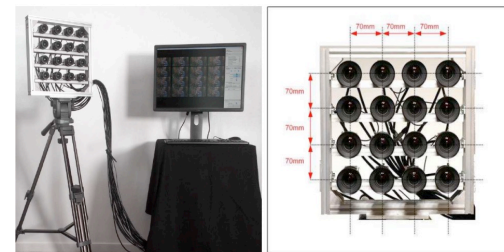
Depth estimation



“Fast and Accurate Optical Flow based Depth Map Estimation from Light Fields”, Y. Chen, M. Alain, A. Smolic; IMVIP 2017

Sparse light field processing

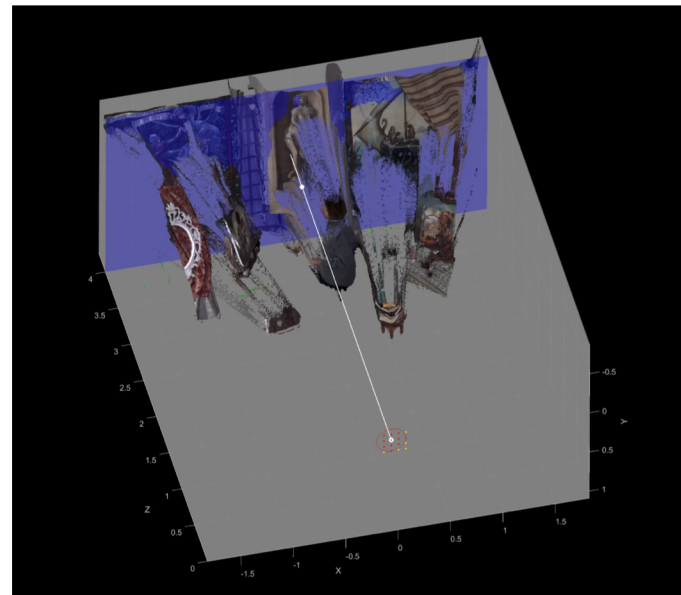
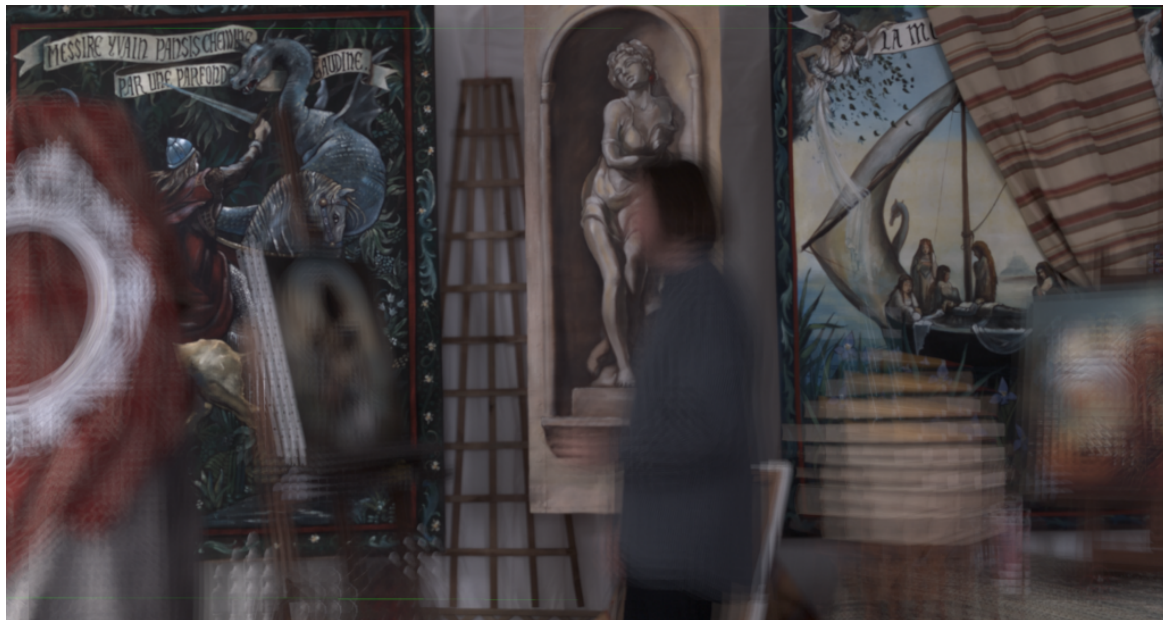
Depth estimation



“Dataset and Pipeline for Multi-view Light-Field Video”, Sabater, Neus; Boisson, Guillaume; Vandame, Benoit; Kerbirou, Paul; Babon, Frederic; Hog, Matthieu; Gendrot, Remy; Langlois, Tristan; Bureller, Olivier; Schubert, Arno; Allie, Valerie; CVPRW 2017

Sparse light field processing

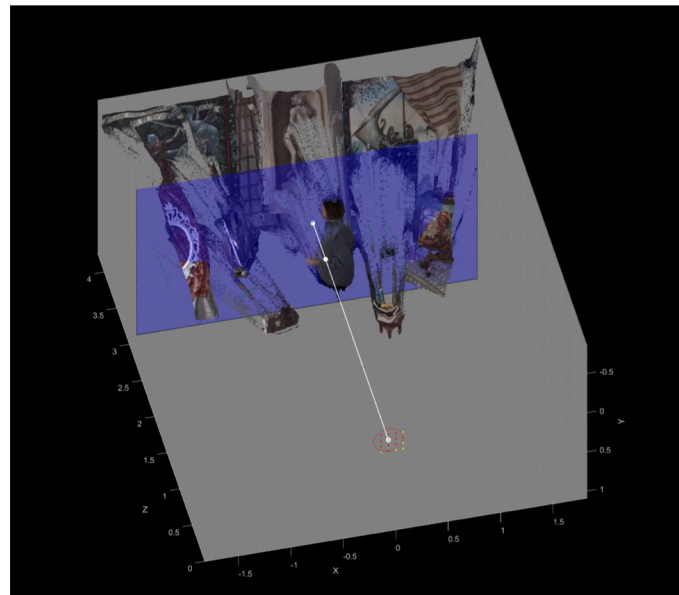
Refocusing – visualization tool



**“Interactive Light Field Tilt-Shift Refocus with Generalized Shift-and-Sum”,
M. Alain, W. Aenchbacher, A. Smolic; ELFI 2019 Workshop**

Sparse light field processing

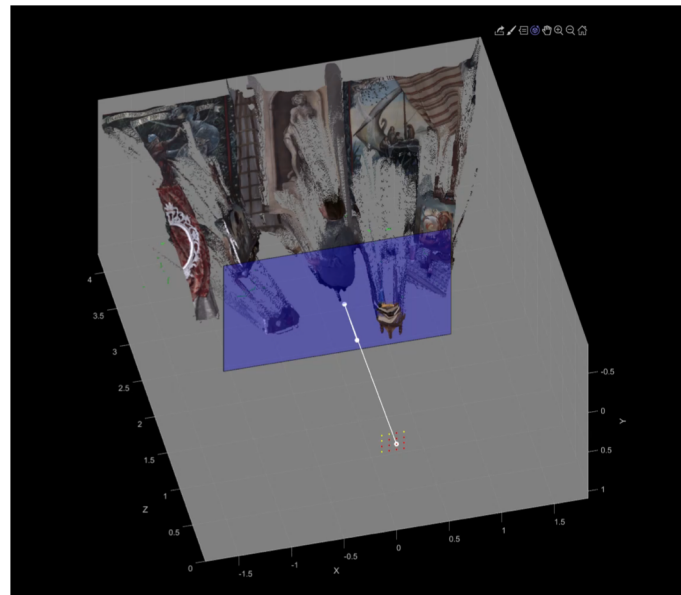
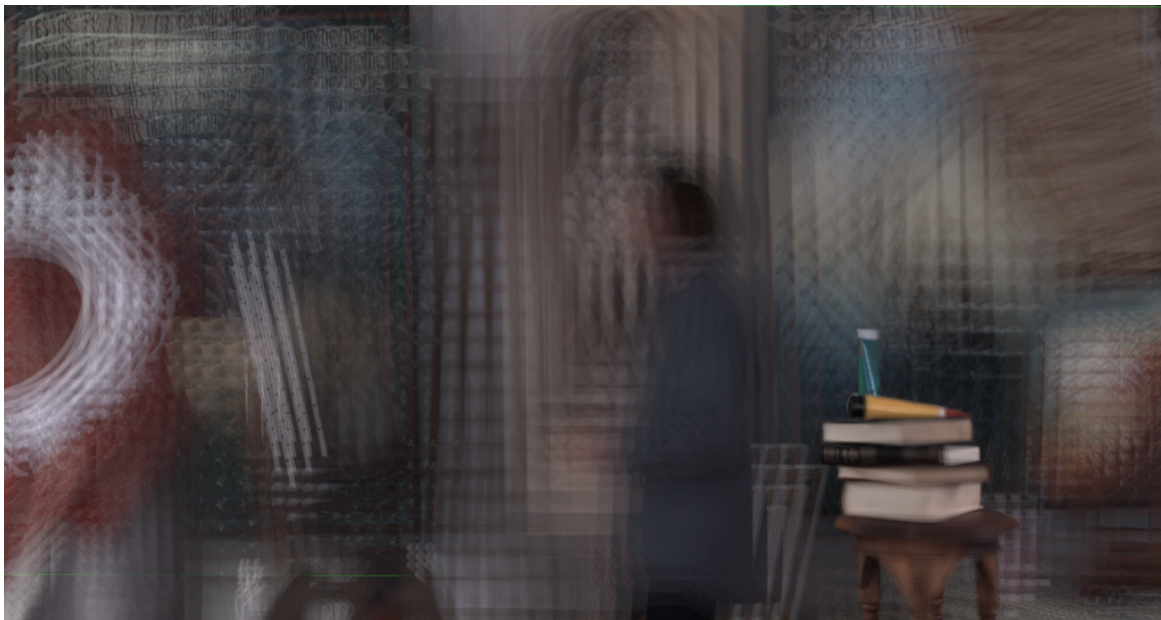
Refocusing – visualization tool



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Sparse light field processing

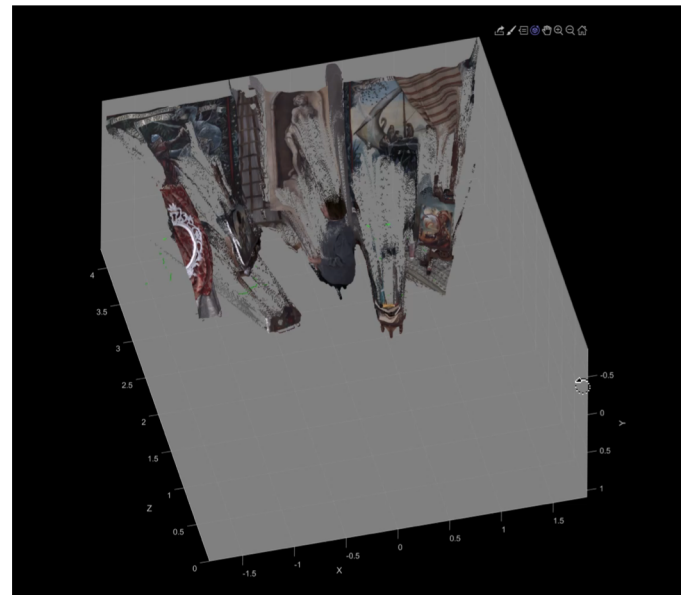
Refocusing – visualization tool



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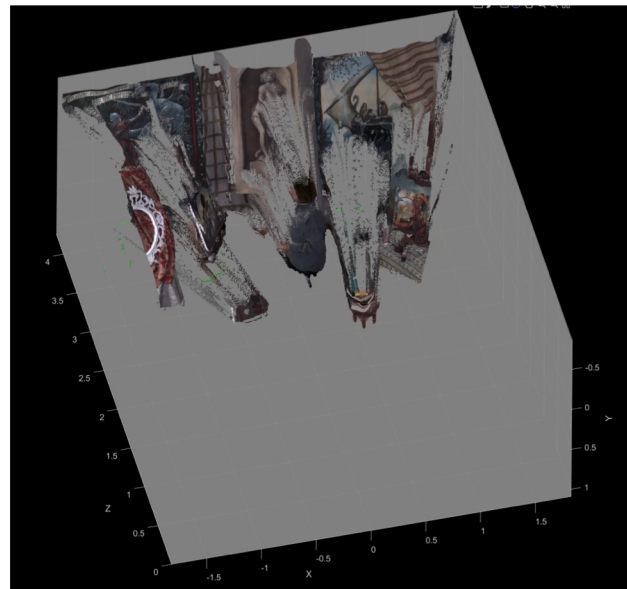
Refocusing – tilted focal plane selection



**“Interactive Light Field Tilt-Shift Refocus with Generalized Shift-and-Sum”,
M. Alain, W. Aenchbacher, A. Smolic; ELFI 2019 Workshop**

Sparse light field processing

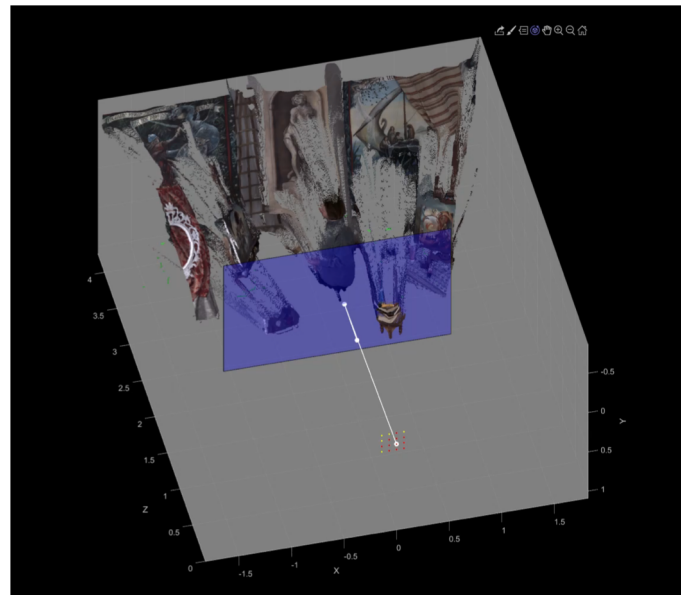
Refocusing – tilted focal plane selection



**“Interactive Light Field Tilt-Shift Refocus with Generalized Shift-and-Sum”,
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Sparse light field processing

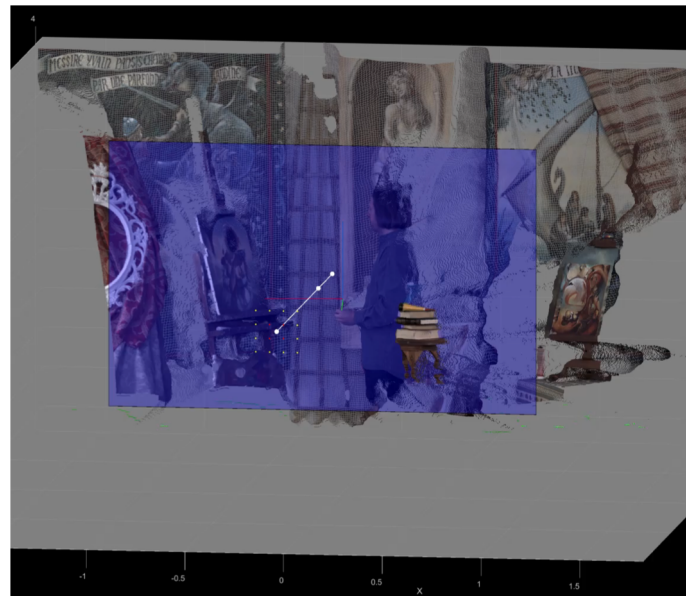
Refocusing – angular aliasing



**“Interactive Light Field Tilt-Shift Refocus with Generalized Shift-and-Sum”,
M. Alain, W. Aenchbacher, A. Smolic; ELFI 2019 Workshop**

Sparse light field processing

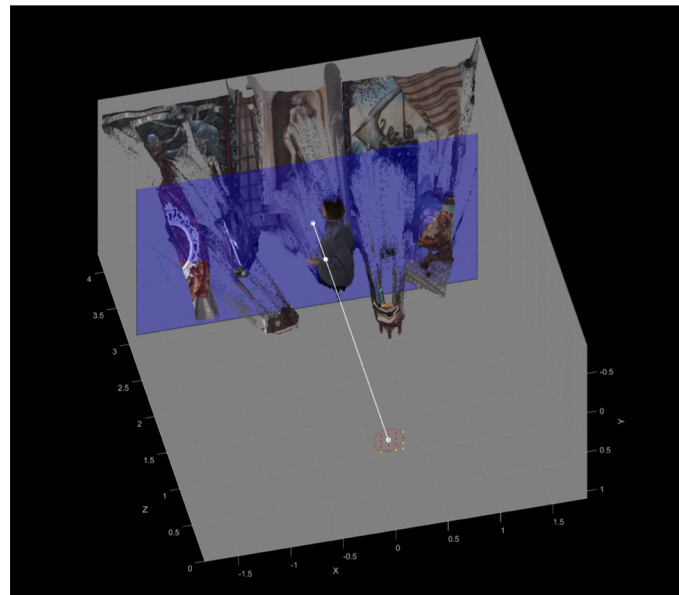
Refocusing – angular aliasing and depth of field



**“Interactive Light Field Tilt-Shift Refocus with Generalized Shift-and-Sum”,
M. Alain, W. Aenchbacher, A. Smolic; ELFI 2019 Workshop**

Sparse light field processing

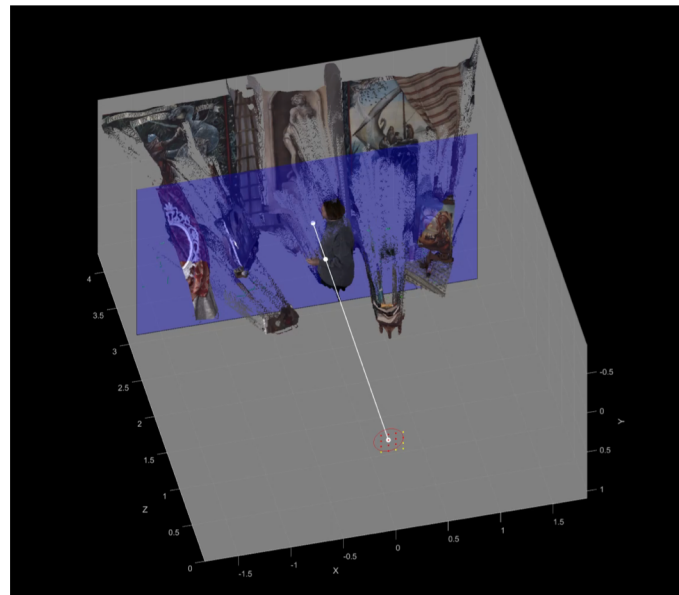
Refocusing – angular aliasing and depth of field



**“Interactive Light Field Tilt-Shift Refocus with Generalized Shift-and-Sum”,
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Sparse light field processing

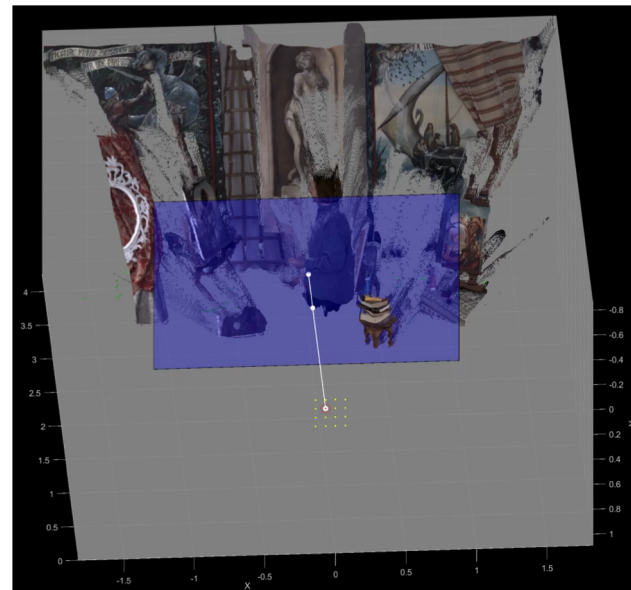
Refocusing – angular aliasing and depth of field



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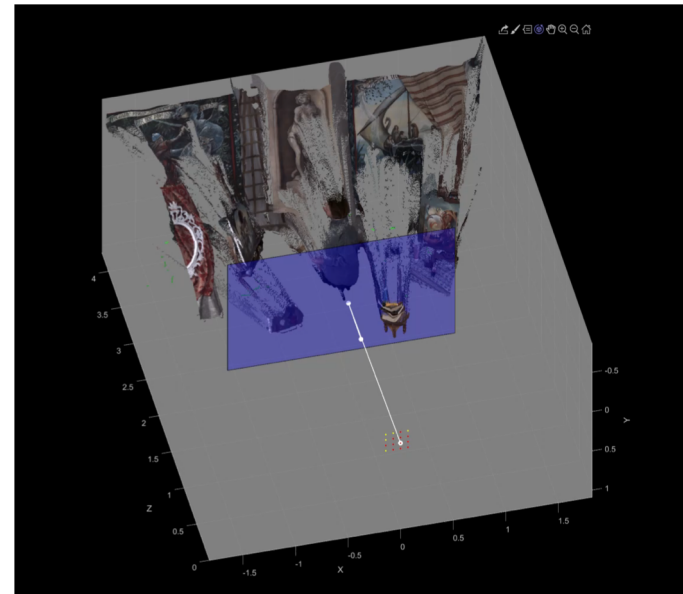
Refocusing – angular aliasing and depth of field



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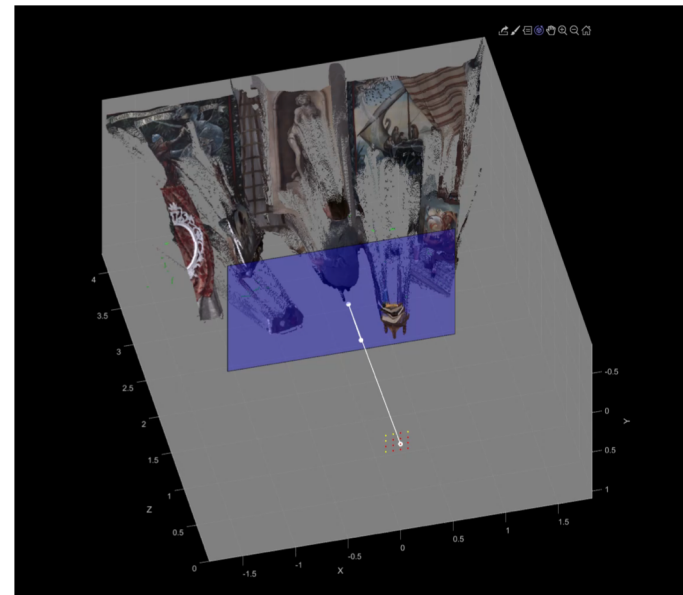
Sparse light field processing

Refocusing – angular aliasing filtering



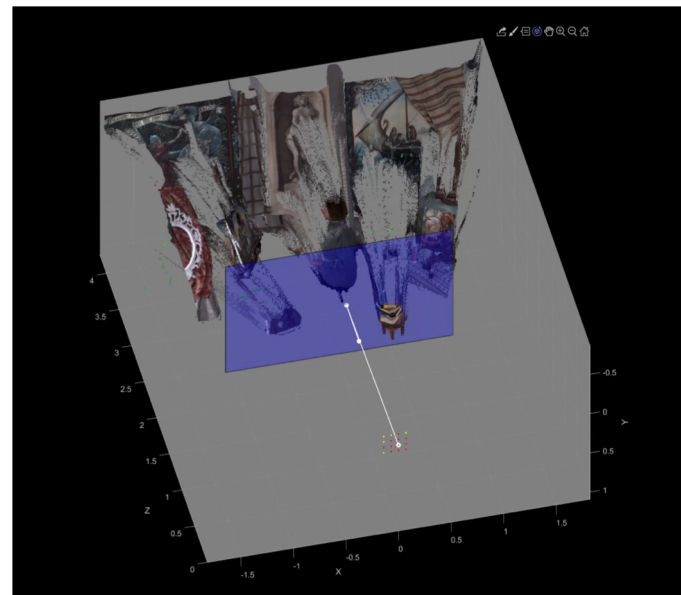
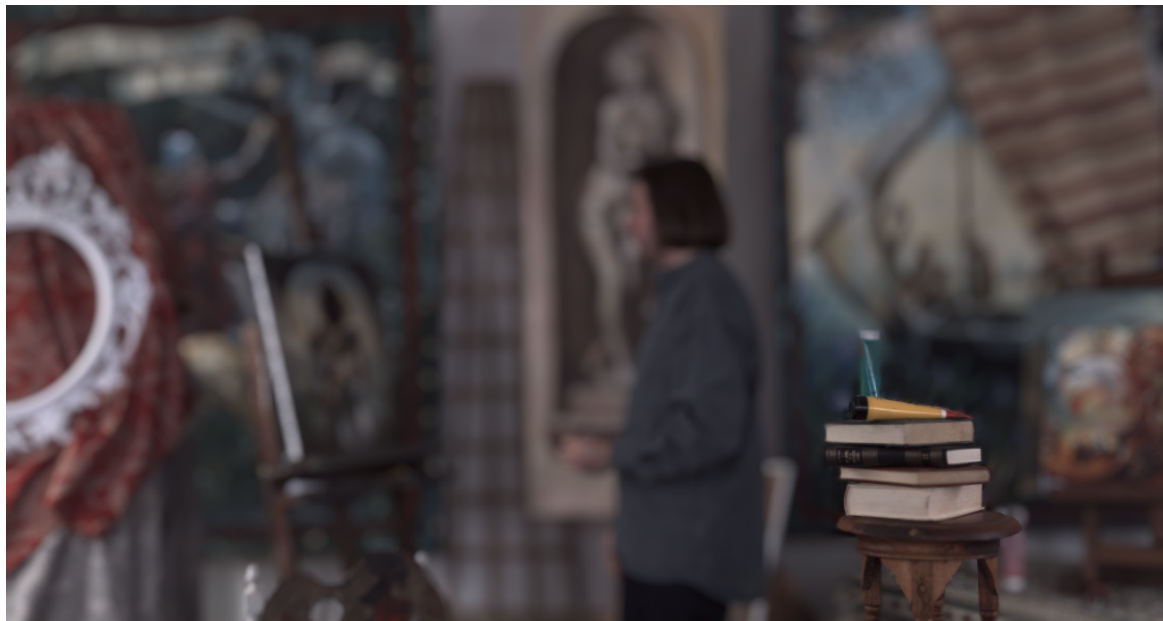
Sparse light field processing

Refocusing – angular aliasing filtering



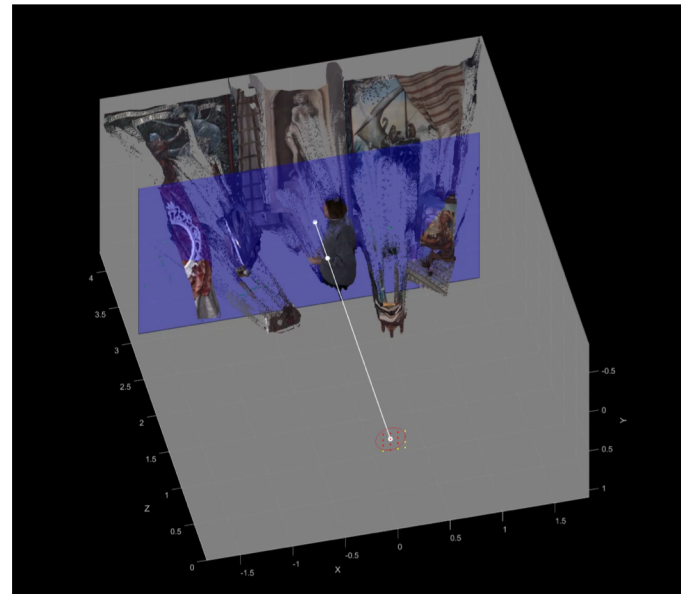
Sparse light field processing

Refocusing – angular aliasing filtering



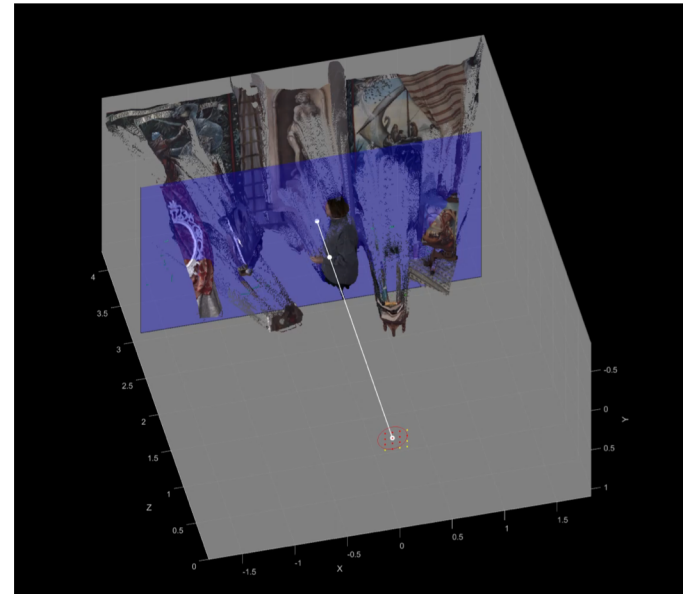
Sparse light field processing

Refocusing – angular aliasing filtering



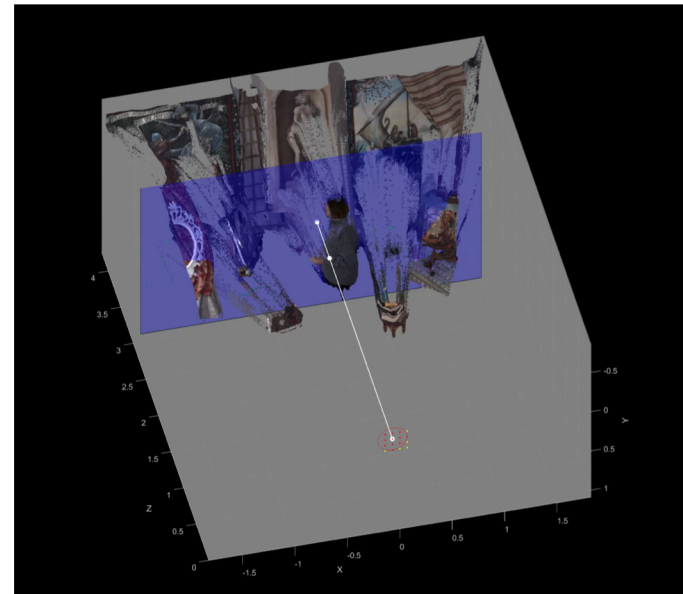
Sparse light field processing

Refocusing – angular aliasing filtering



Sparse light field processing

Refocusing – angular aliasing filtering



Conclusion

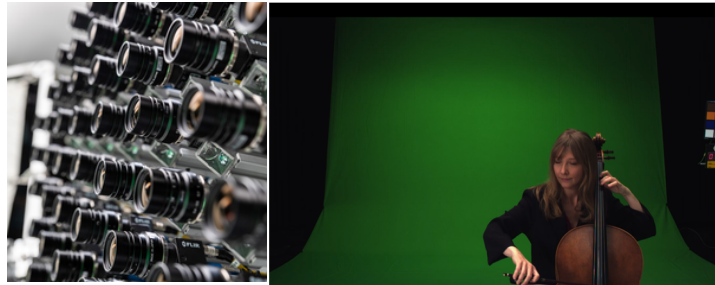
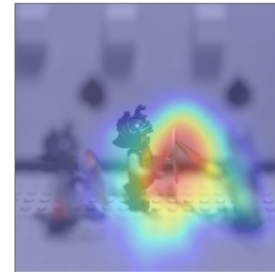
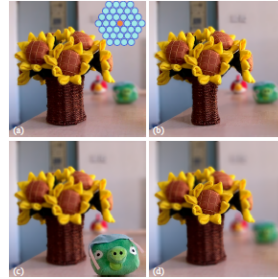
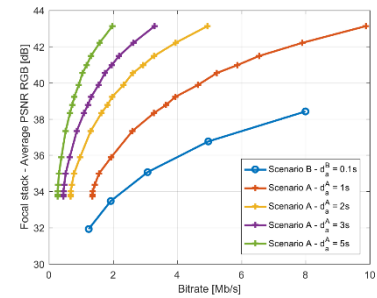
Challenges and opportunities

- New high level applications built on new low level processing
- Specific algorithm for sparse vs dense light fields
- Angular aliasing filter needed for high level tasks
- Improved performances on existing low level tasks
- Increased computational complexity and data volume

Conclusion

Future work

- Light field cloud processing and streaming
- Easy editing interface for professional and casual users
- Study visual attention models for light field imaging
- Extension to light field videos





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The University of Dublin

V-SENSE

Many Thanks!

- <https://v-sense.scss.tcd.ie/research/light-field-imaging/>
- <https://github.com/V-Sense>