Unifying the refocusing algorithms and parameterizations for traditional and focused plenoptic cameras

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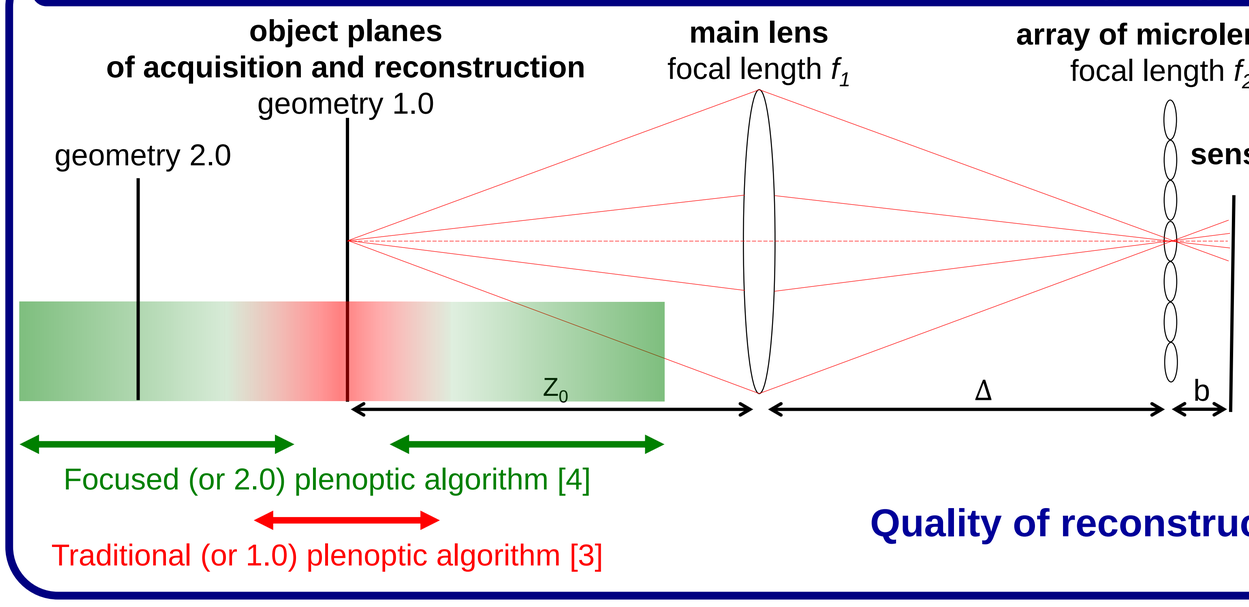
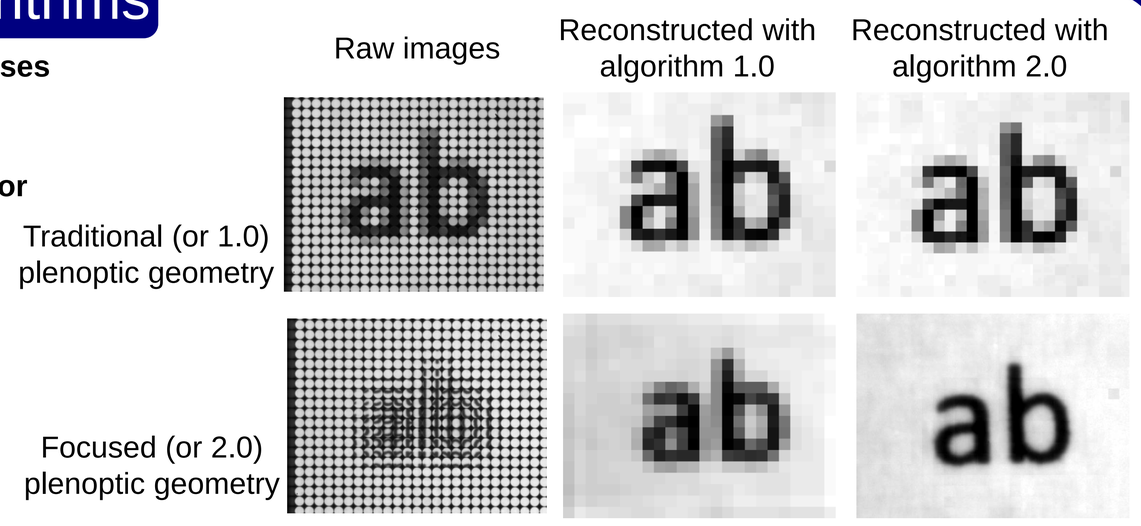
Introduction

A plenoptic camera allows to acquire and separate spatial and directional information of the light coming from a scene [1, 2]. It allows applications such as refocusing at different depths from the one where the image has been acquired. In the literature, different refocusing algorithms are presented for several optical plenoptic configurations [3 - 6]. We have previously shown the continuity between these optical designs, and the similarities and differences between the associated algorithms [7]. Here we propose a unique parameterization of the light rays in a plenoptic setup, allowing the development of a unique refocusing algorithm valid for any plenoptic configurations, based on the integration of étendues' intersections in the image-space. With this method, we aim at refocusing images at any distances from the camera, without the discontinuity due to the change of optical configurations.

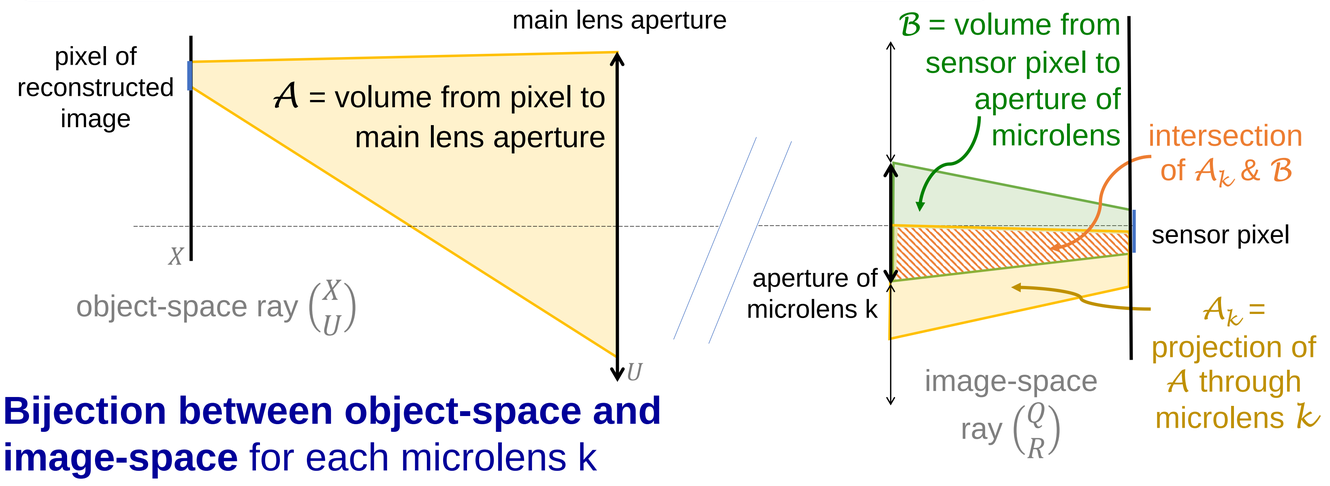
1. Validity domains of historical refocusing algorithms





Quality of reconstructed images depends on both the optical design and the algorithm used.

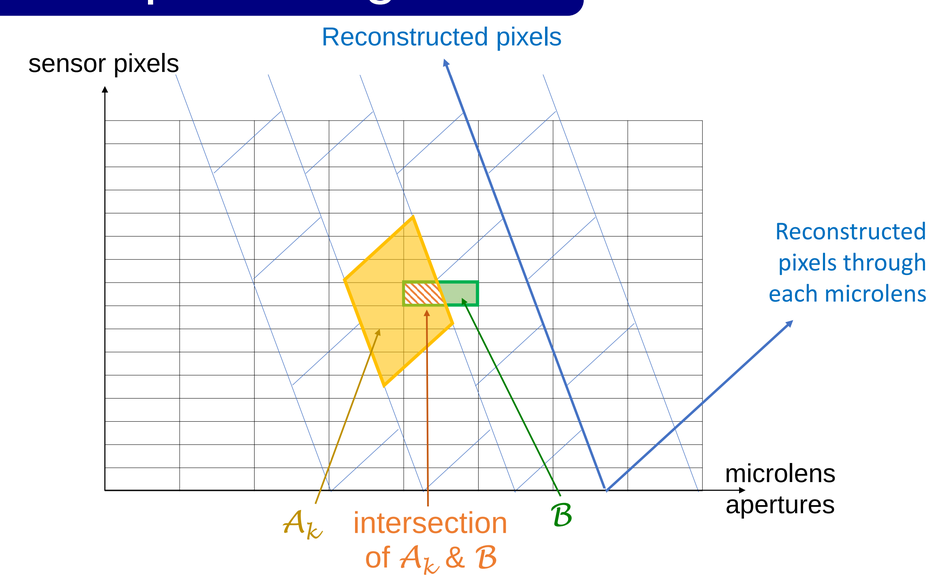
2. Parametrization of the Light-Field



Bijection between object-space and image-space for each microlens k

$$\begin{pmatrix} Q \\ R \end{pmatrix} = M \begin{pmatrix} X \\ U \end{pmatrix} + \frac{b}{f_2}\begin{pmatrix} 0 \\ k \end{pmatrix} \text{ with } M = \frac{1}{Z_0}\begin{pmatrix} -\Delta & Z_0 + \Delta - \frac{Z_0}{f_1} \\ \frac{\Delta b}{f_2} - (b+\Delta) & b + Z_0 + \Delta - \frac{(b+\Delta)Z_0}{f_1} - \frac{(Z_0+\Delta)b}{f_2} + \frac{\Delta Z_0 b}{f_1 f_2} \end{pmatrix}$$

3. Proposed algorithm



Intersection of étendues in the image space

For each pixel X in the image to reconstruct & **For each microlens k**:

- Transform of the étendue defined by pixel X and main lens aperture U :

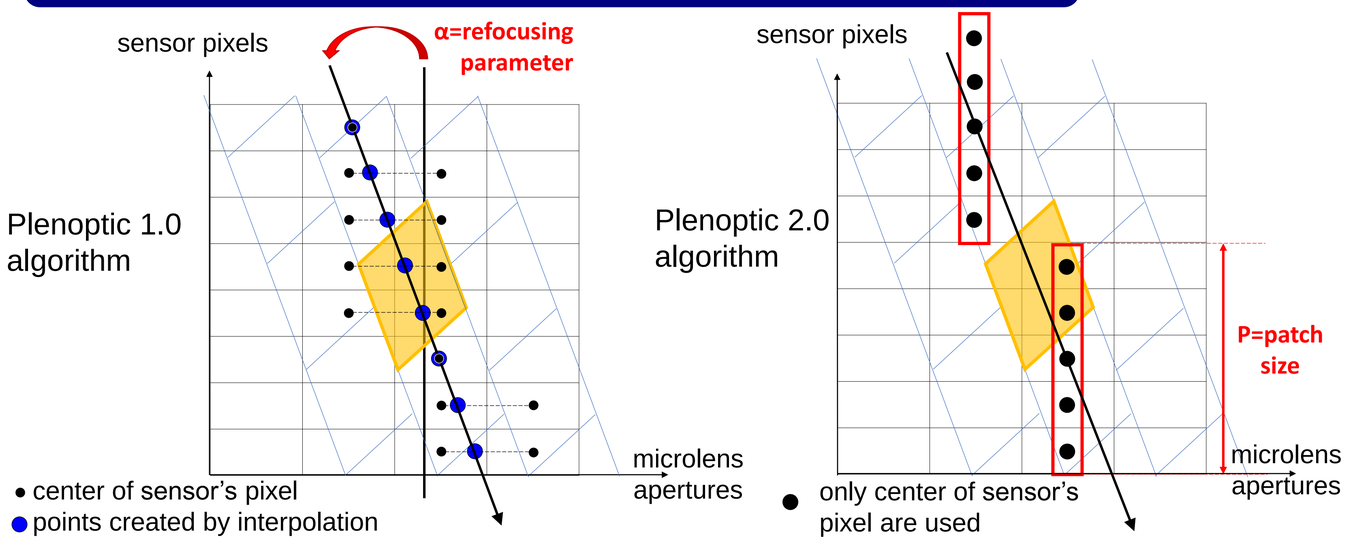
$$\begin{pmatrix} Q \\ R \end{pmatrix} = M \begin{pmatrix} X \\ U \end{pmatrix} + \frac{b}{f_2}\begin{pmatrix} 0 \\ k \end{pmatrix}$$

- For each pixel i on the sensor:
  - étendues of intersection $\begin{pmatrix} Q \\ R \end{pmatrix}$ & $\begin{pmatrix} K \\ I \end{pmatrix}$ defined by microlens k and pixel i
  - add the weighted contribution of pixel i to reconstructed pixel X

$$\mathrm{I}(X) = \sum_{lens\ k} \sum_{pixel\ i} \text{Pixel value}(i) \frac{\text{étendue}\left(\begin{pmatrix} Q \\ R \end{pmatrix} \cap \begin{pmatrix} K \\ I \end{pmatrix}\right)}{\text{étendue}\begin{pmatrix} Q \\ R \end{pmatrix}}$$

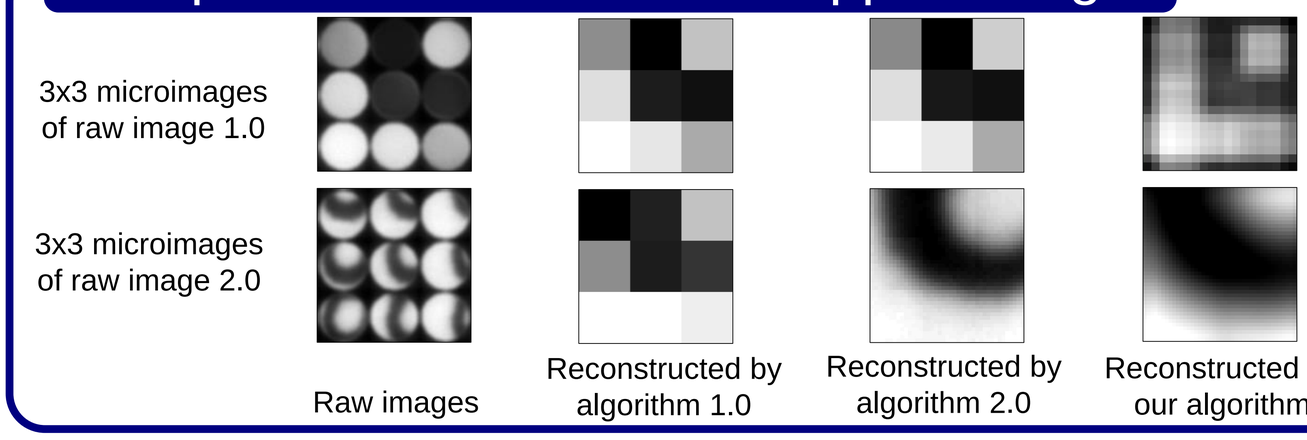
First approximation for exact integration étendue = volume.

4. Comparison with historical algorithms



Integration is approximated on a reduced set of samples

5. Experimental results on cropped images



Conclusions

- Unification of the two historical algorithms.
- Algorithm based on the intersection of étendues instead of using pixels as points.
- First implementation of algorithm → validation of the idea.
- Future work: improving execution time.

References

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VOXEL project EU's Horizon 2020 nº 665207