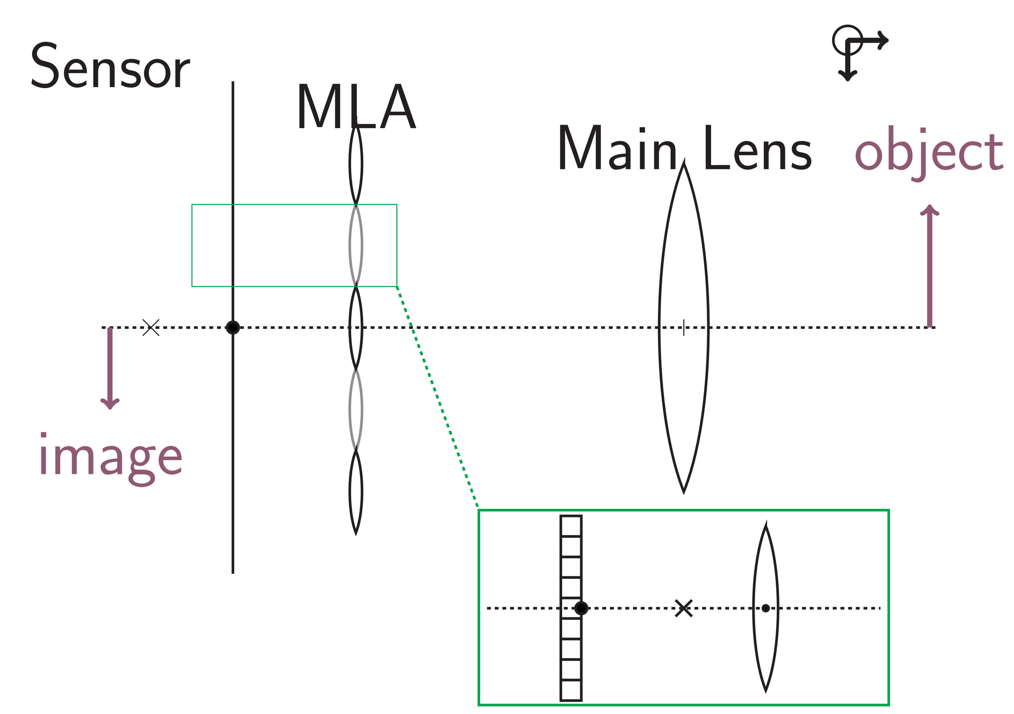
Blur Aware Calibration of Multi-Focus Plenoptic Camera

Mathieu Labussière[1], Céline Teulière[1], Frédéric Bernardin[2] and Omar Ait-Aider[1]

[1]Université Clermont-Auvergne, CNRS, SIGMA Clermont, Institut Pascal, F-63000 Clermont-Ferrand, France,
[2]Cerema, Équipe-projet STI, 10 rue Bernard Palissy, F-63017 Clermont-Ferrand, France.

Micro-Lenses Array (MLA) based (Multi-focus) Plenoptic Camera

- This paper focuses on the calibration of plenoptic cameras based on a MLA placed between the main lens and the photo-sensitive sensor [1, 2].
- The MLA consists of different lens types with different focal lengths which are focused on different planes.
- Calibration aims to determine the parameters of the camera model.



Our contributions

- Our calibration method is the first:
  - proposing a single optimization process that retrieves intrinsic and extrinsic parameters,
  - including a more complete model of the multi-focus plenoptic camera,
  - working directly from raw images.
- This is achieved by introducing a new Blur Aware Plenoptic (BAP) feature defined in raw image space that enables us to handle the multi-focus case.

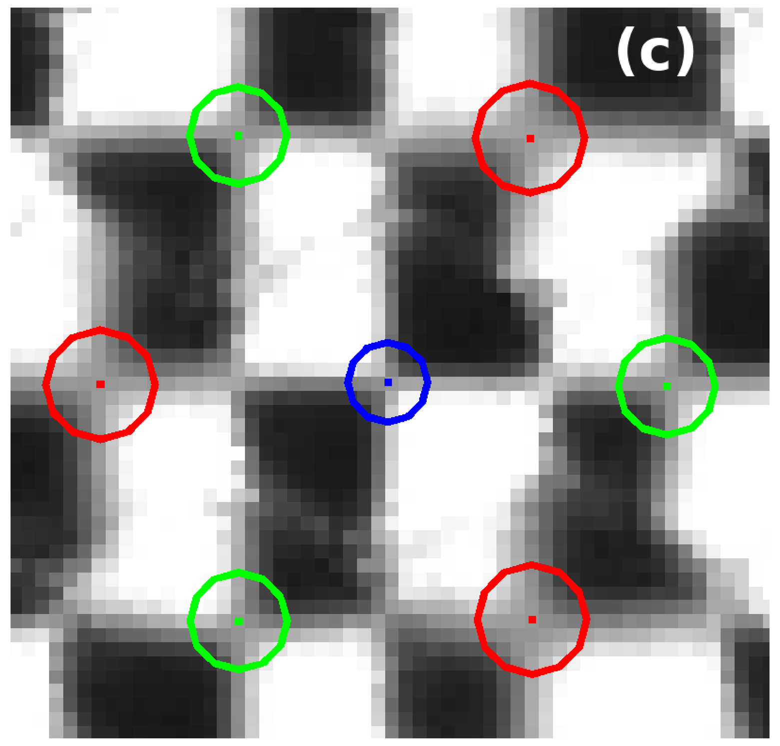
Leveraging blur information with our Blur Aware Plenoptic (BAP) Feature

- The blurred image of a point on the sensor is circular in shape and is called the blur circle.
- We introduce a new Blur Aware Plenoptic (BAP) feature characterized by its center and its radius:

$$\boldsymbol{p} = (u, v, \rho)\,.$$

- Our blur aware projection model:

$$\begin{bmatrix} u \\ v \\ \rho \\ 1 \end{bmatrix} \propto \mathcal{P}(i,k,l)\cdot \boldsymbol{T}_{\mu}(k,l)\cdot \varphi\left(\boldsymbol{K}(F)\cdot \boldsymbol{T}_c \cdot \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}\right).$$

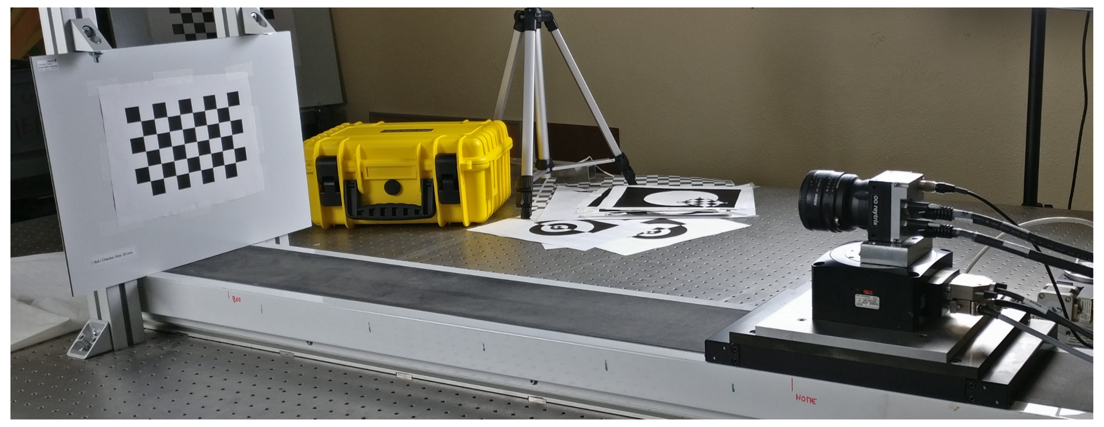


Our experimental setup

- For our experiments we use a `Raytrix R12` color 3D-light-field-camera with:
  - a mounted lens of 50mm focal length,
  - a MLA composed of 3 micro-lens types,
  - a pixel size of $s = 5.5\mu$m.
- We build three datasets corresponding to three different focus distances h:
  - R12-A for $h = 450$ mm,
  - R12-B for $h = 1000$ mm,
  - R12-C for $h = \infty$.

Quantitative evaluation in a controlled environment

- The camera is mounted on a linear motion table with micro-metric precision. We acquired several images with known relative motion between each frame.



	R12-A		R12-B		R12-C		All
Error [%]	$\bar{\epsilon}_z$	σ_z	$\bar{\epsilon}_z$	σ_z	$\bar{\epsilon}_z$	σ_z	$\bar{\epsilon}_z$
Ours	3.73	1.48	3.32	1.17	2.95	1.35	**3.33**
Noury et al. [3]	6.83	1.17	1.16	1.06	2.70	0.86	3.56
`RxLive` (v.4.0)	4.63	2.51	4.26	5.79	11.52	3.22	6.80

Table 1: Relative translation error (the mean error $\bar{\epsilon}_z$ and its standard deviation σ_z) along the z-axis with respect to the ground truth displacement.

- Our method shows:
  - a stable behavior across all datasets,
  - the lowest mean error on all datasets.

Conclusion

- We introduced a new Blur Aware Plenoptic (BAP) feature:
  - defined in raw image space that enables us to handle the multi-focus case,
  - exploited in our single calibration process,
  - to retrieve parameters of a more complete camera model.
- Our calibration method is validated by qualitative experiments and quantitative evaluations.
- Our open-source code and datasets are publicly available on github.com/comsee-research.

Main References

[1] Ren Ng et al. *Light Field Photography with a Hand-held Plenoptic Camera*. Tech. rep. Stanford University, 2005, pp. 1–11.
[2] Christian Perwaß and Lennart Wietzke. "Single Lens 3D-Camera with Extended Depth-of-Field". In: *Human Vision and Electronic Imaging XVII*. Vol. 49. 431. SPIE, 2012, p. 829108.
[3] Charles Antoine Noury, Céline Teulière, and Michel Dhome. "Light-Field Camera Calibration from Raw Images". In: *DICTA 2017 – International Conference on Digital Image Computing: Techniques and Applications* (2017), pp. 1–8.