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V-SENSE

High Dynamic Range Light Fields via Weighted Low Rank Approximation

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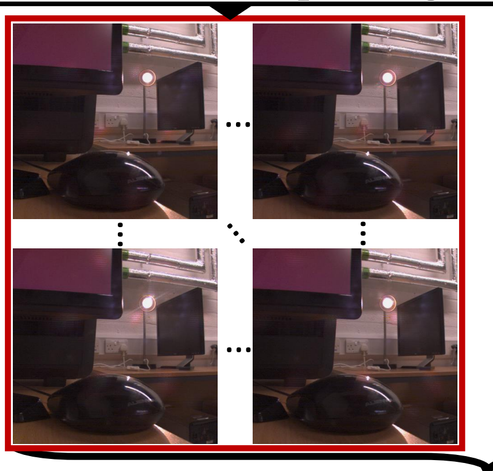
Context

- **Dense Light Fields** are typically captured with lenslet-based plenoptic cameras with very **limited Dynamic Range**.
- **Low rank matrix completion (LRMC)** has been used successfully for **fusing** multiple exposure images into a HDR image (e.g.[1]) and for completion of dense Light Fields [2].
- We propose **multiple exposure Light Field capture and fusion via Weighted Low Rank Approximation (WLRA)**

Overview

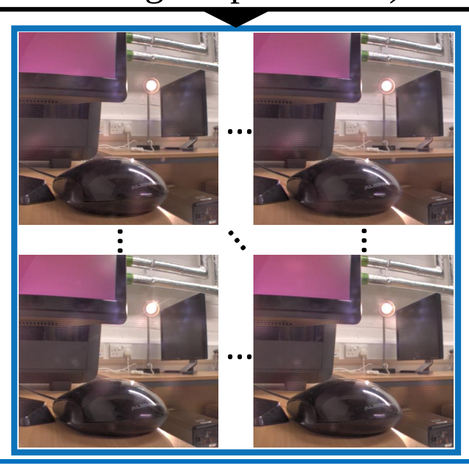
Low exposure — Plenoptic capture — *High exposure*

RAW De-multiplexing + Soft saturation detection



Weighted Low Rank Approximation
(recovery of overexposed areas in high exposure LF)

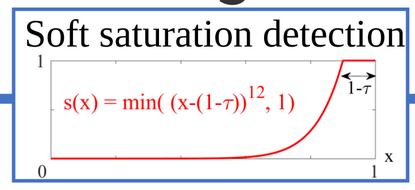
HDR Light Field
(keeping only the recovered high exposure)



RAW Data Processing

RAW Soft Saturation map

Soft saturation detection



Lenslet RAW Pixel data

RAW Demultiplexing

RGB to Yu'v'

Saturation to weights $w = \frac{1-s}{s+1/w_{max}}$

Light Field Views

Weight maps per View

Weighted Low Rank Approximation

Columns of matrix M: vectorized views
Columns of matrix W: vectorized weight maps

$$\min_X \ \text{rank}(X) \quad \text{s.t.} \quad X = Z, \quad \|W \circ (Z - M)\|_F^2 \leqslant \epsilon$$

($\circ$: element-wise multiplication)

Alternating Direction Method of Multipliers

Augmented Lagrangian function:

$$\mathcal{L}(X, Z, \Lambda, \rho) = \text{rank}(X) + \text{Tr}(\Lambda^\top (X - Z)) + \frac{\rho}{2} \|X - Z\|_F^2$$

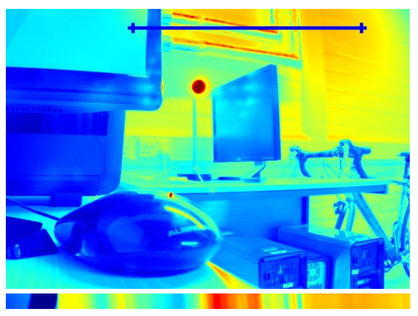
X update (Z fixed)	$X^{(k)} = \arg\min_X \mathcal{L}(X, Z^{(k-1)}, \Lambda^{(k-1)}, \rho^{(k-1)})$
Z update (X fixed)	$Z^{(k)} = \arg\min_{Z \text{ s.t. } \|W \circ (Z-M)\|_F^2 \leqslant \epsilon} \mathcal{L}(X^{(k)}, Z, \Lambda^{(k-1)}, \rho^{(k-1)})$
Lagrangian multipliers update	$\Lambda^{(k)} = \Lambda^{(k-1)} + \rho^{(k-1)} \cdot (X^{(k)} - Z^{(k)})$
Penalty parameter update	$\rho^{(k)} = t \cdot \rho^{(k-1)}$ (with $t > 1$)

Results

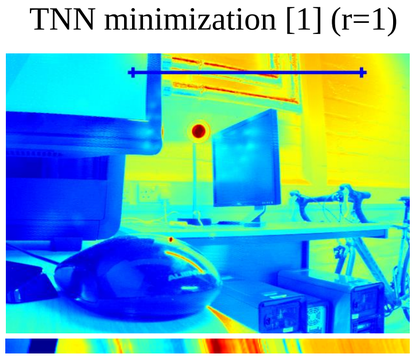
Rank vs Truncated Nuclear Norm

TNN minimization [1] (r=100)

TNN minimization [1] (r=20)



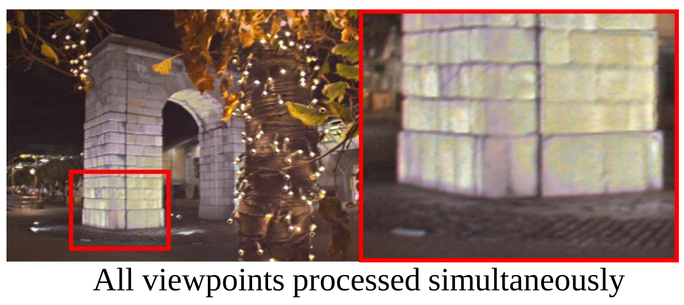
TNN minimization [1] (r=1)



Our rank minimization

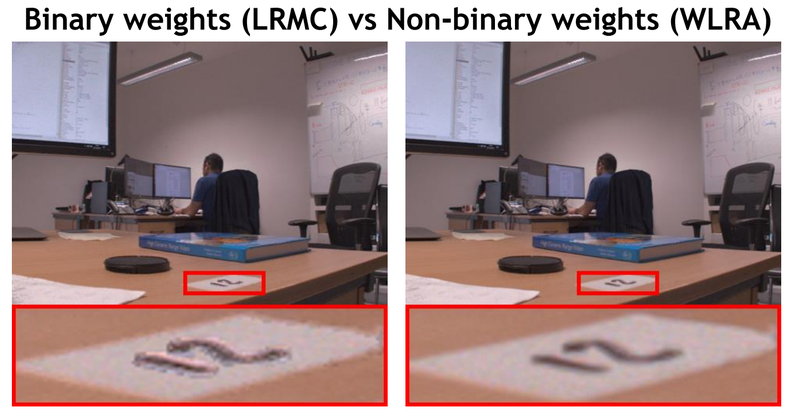
Independent vs Simultaneous Viewpoint processing

Independent viewpoint processing



All viewpoints processed simultaneously

Binary weights (LRMC) vs Non-binary weights (WLRA)



Binary weights (LRMC [2]) Non-binary weights (WLRA)

Conclusion

- **True rank minimization** (instead of truncated nuclear norm) ➔ necessary for processing different viewpoints simultaneously.
- **Process views simultaneously** ➔ less noise
- **Soft Saturation + WLRA** ➔ smooth transition at the boundary of the over-exposed areas

References

[1] C. Lee and E. Y. Lam, "Computationally efficient truncated nuclear norm minimization for high dynamic range imaging," *IEEE TIP*, Sep. 2016.
[2] M. Le Pendu, X. Jiang and C. Guillemot, "Light field inpainting propagation via low rank matrix completion," *IEEE TIP*, Apr. 2018.

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