

IEEE RESEARCH AND APPLICATIONS OF PHOTONICS IN DEFENSE

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Compressive Spectral-Video by Optimal 3D/4D-Sphere Packing

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Chile



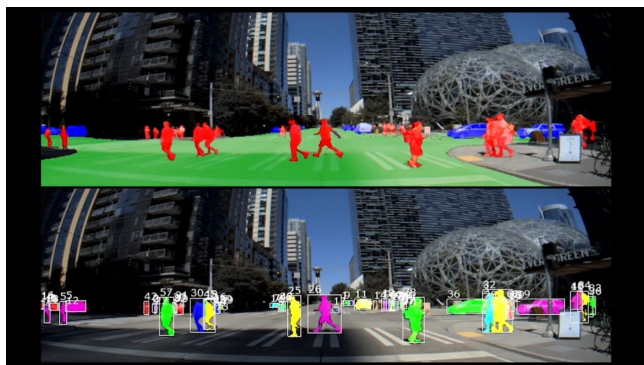
PONTIFICIA UNIVERSIDAD
CATOLICA
DE VALPARAISO



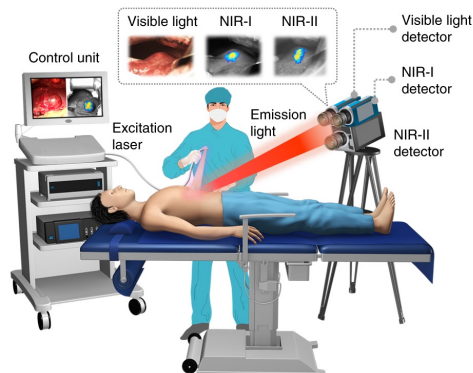
12 September 2023



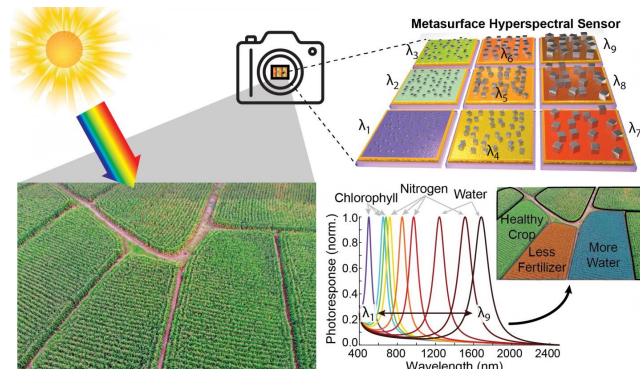
Applications of Spectral-Video



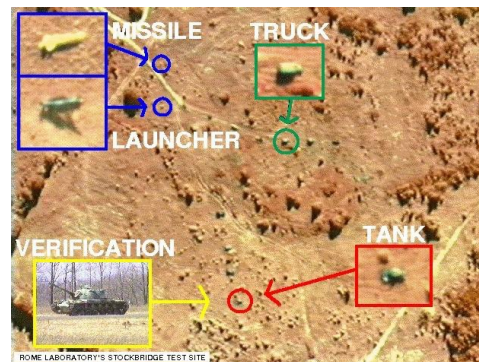
Self-driving car



Guided surgery

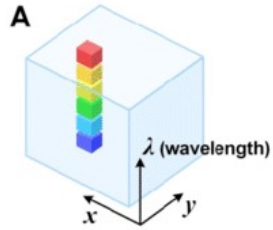


Smart farming

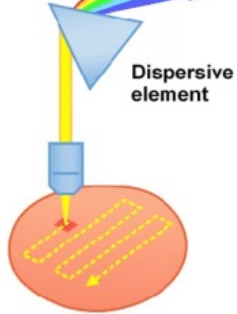


Camouflage detection

Traditional Approaches to Capture Spectral Images

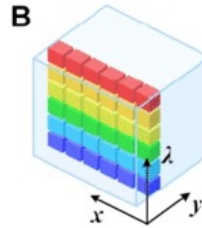


Linear array /
2D array
detector

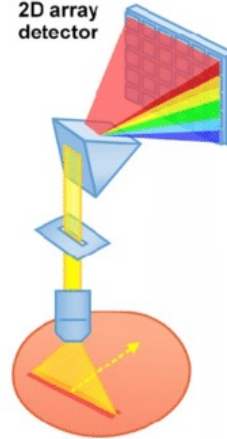


Point scan

Spectral res: high
Speed: low

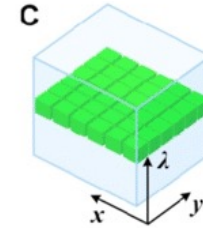


2D array
detector

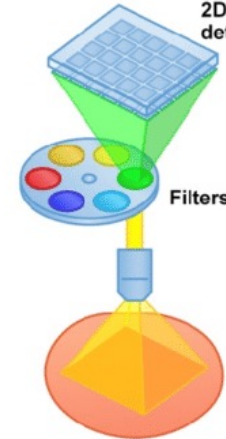


Line scan

Spectral res: high
Speed: medium



2D array
detector

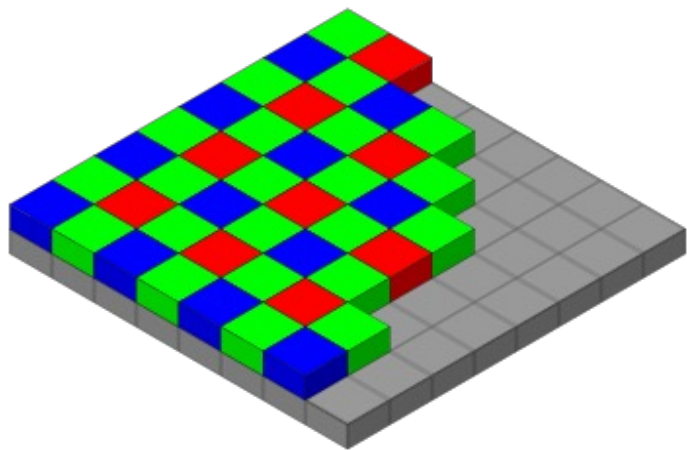


Wavelength scan

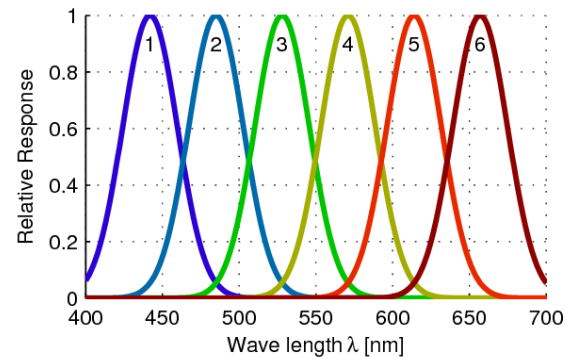
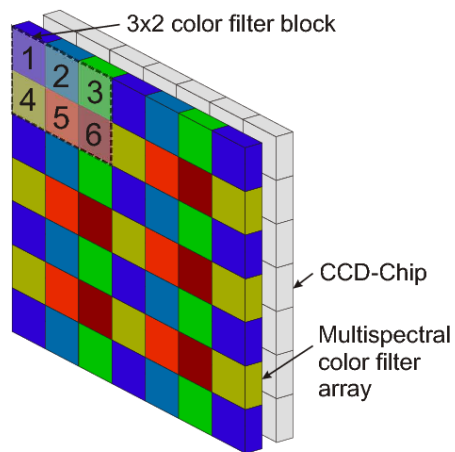
Spectral res: low - high
Speed: medium / high

Multispectral Filter Arrays (MSFA)

Bayer Filter



Multispectral Filter



MSFA Design using Sphere Packing

Random

4	5	2	9	8	11	13	7	14	6	10	15	12	3	1	16
5	11	14	13	2	10	9	15	6	8	7	1	4	3	12	16
16	7	1	6	14	8	11	13	3	2	15	4	10	9	5	12
16	9	5	4	10	7	1	6	12	8	3	2	15	11	13	14
9	7	13	15	10	3	12	2	1	16	14	6	8	4	5	11
15	2	4	11	13	1	16	6	14	5	10	9	7	12	8	3
14	7	11	9	6	4	3	2	15	8	13	16	10	12	5	1
7	15	5	11	10	14	13	4	8	9	12	16	3	2	6	1
2	6	1	5	9	11	3	4	16	8	13	10	14	7	12	15
7	15	10	12	1	9	16	11	3	8	6	13	14	5	2	4
6	12	2	14	7	4	1	15	11	5	16	10	13	8	3	9
11	8	12	14	15	7	1	10	13	4	3	9	16	2	5	6
5	2	13	3	15	1	9	6	7	12	8	14	10	11	16	4
6	9	2	15	7	13	16	12	10	4	1	8	11	14	3	5
7	1	12	13	16	3	2	8	14	11	6	15	5	9	4	10
10	11	6	12	13	14	2	9	1	15	4	16	3	7	5	8

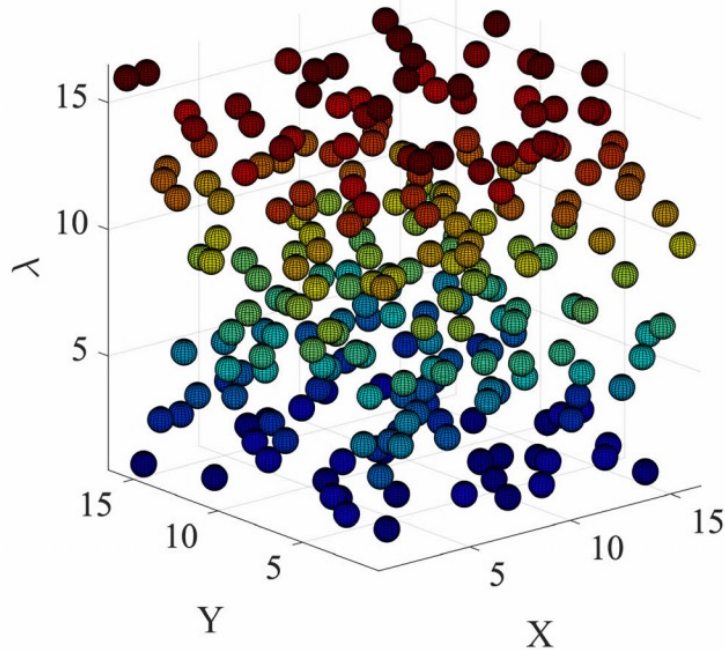
Designed

9	12	15	2	5	8	11	14	1	4	7	10	13	16	3	6
14	1	4	7	10	13	16	3	6	9	12	15	2	5	8	11
3	6	9	12	15	2	5	8	11	14	1	4	7	10	13	16
8	11	14	1	4	7	10	13	16	3	6	9	12	15	2	5
13	16	3	6	9	12	15	2	5	8	11	14	1	4	7	10
2	5	8	11	14	1	4	7	10	13	16	3	6	9	12	15
7	10	13	16	3	6	9	12	15	2	5	8	11	14	1	4
12	15	2	5	8	11	14	1	4	7	10	13	16	3	6	9
1	4	7	10	13	16	3	6	9	12	15	2	5	8	11	14
6	9	12	15	2	5	8	11	14	1	4	7	10	13	16	3
11	14	1	4	7	10	13	16	3	6	9	12	15	2	5	8
16	3	6	9	12	15	2	5	8	11	14	1	4	7	10	13
5	8	11	14	1	4	7	10	13	16	3	6	9	12	15	2
10	13	16	3	6	9	12	15	2	5	8	11	14	1	4	7
15	2	5	8	11	14	1	4	7	10	13	16	3	6	9	12
4	7	10	13	16	3	6	9	12	15	2	5	8	11	14	1

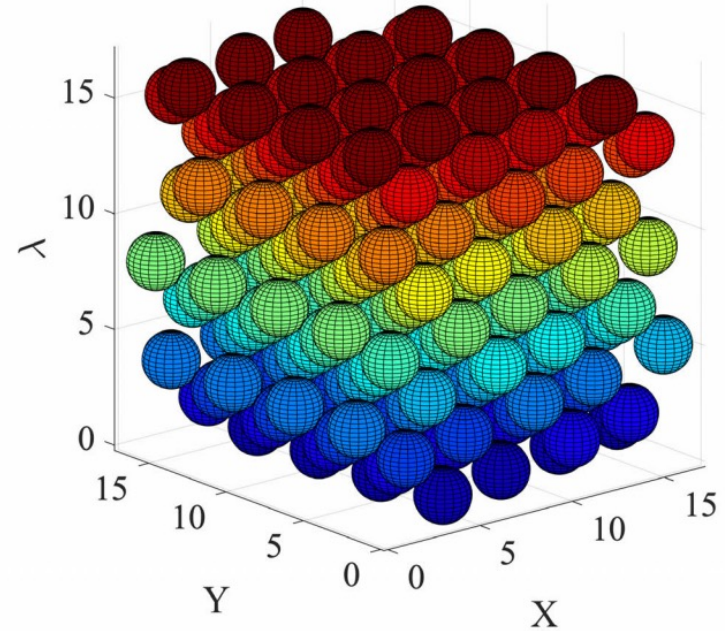
N. Diaz, A. Alvarado, P. Meza, F. Guzmán and E. Vera, "Multispectral Filter Array Design by Optimal Sphere Packing," in IEEE Transactions on Image Processing, vol. 32, 2023.

MSFA Design using Sphere Packing

Random

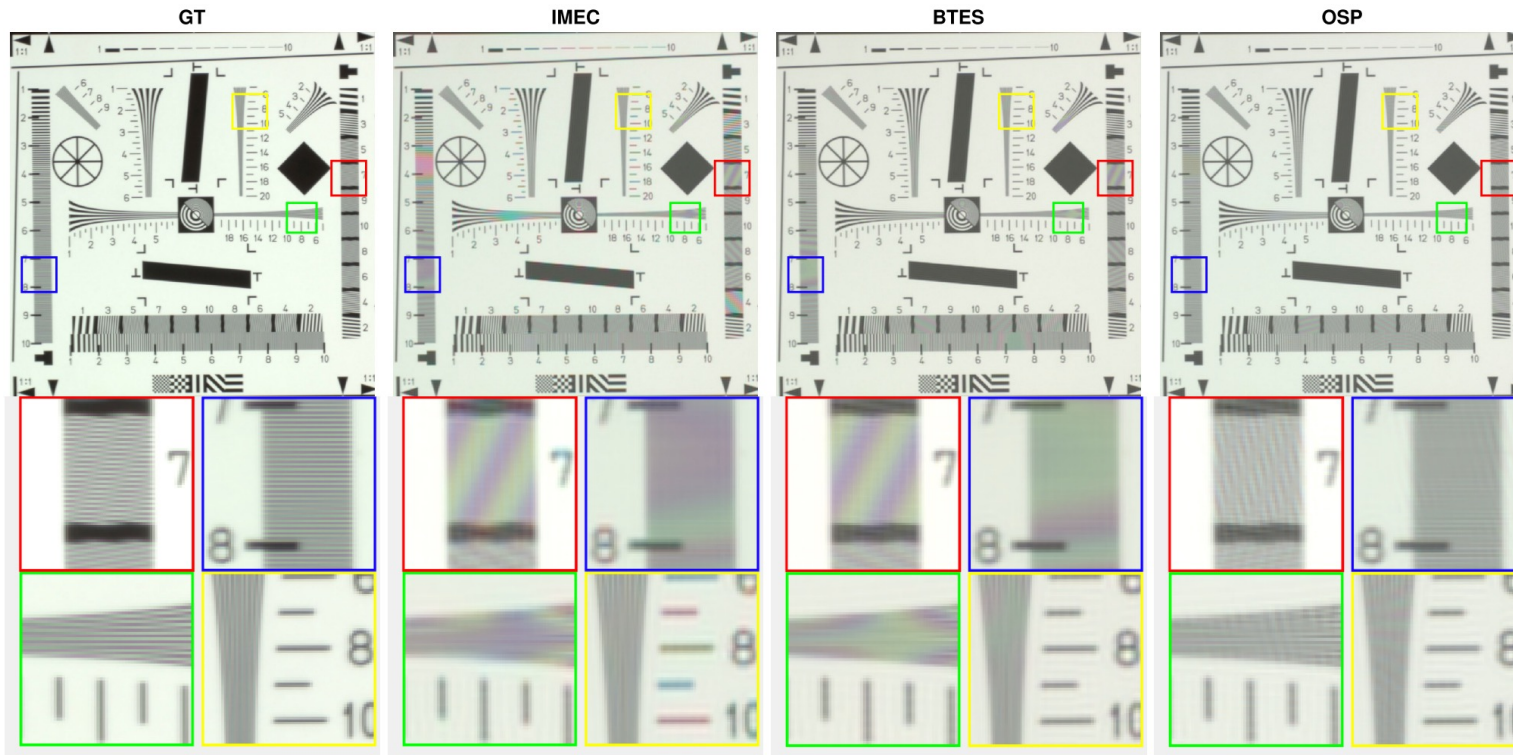


Designed



N. Diaz, A. Alvarado, P. Meza, F. Guzmán and E. Vera, "Multispectral Filter Array Design by Optimal Sphere Packing," in IEEE Transactions on Image Processing, vol. 32, 2023.

Reconstruction Results using MSFA



N. Diaz, A. Alvarado, P. Meza, F. Guzmán and E. Vera, "Multispectral Filter Array Design by Optimal Sphere Packing," in IEEE Transactions on Image Processing, vol. 32, 2023.



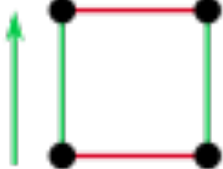
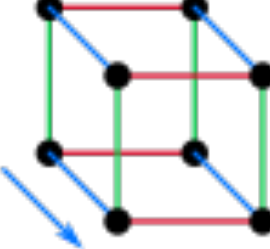
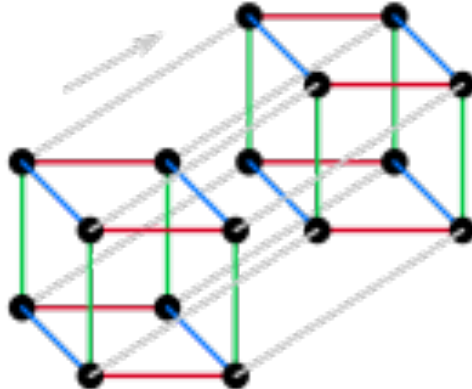

What is Sphere Packing?

The sphere packing problem asks for the densest packing of R^n with congruent balls. Equivalent to answer the question:

What is the largest fraction of R^n that can be covered by congruent balls with disjoint interiors?

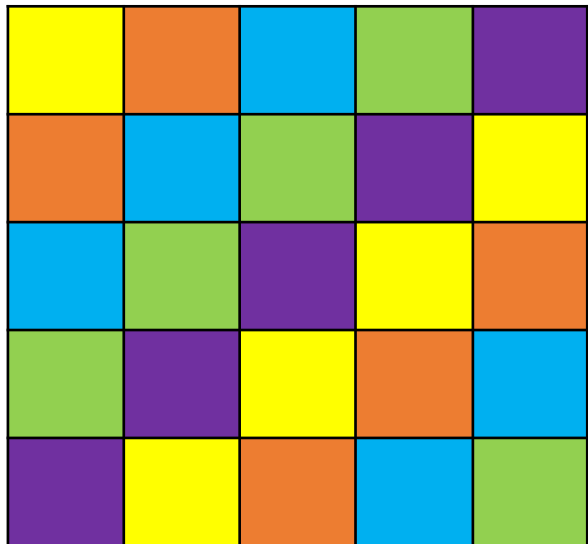


Optimal Sphere Packing Density

					<div style="display: flex; flex-direction: column; align-items: center;"> X Y Z W  </div>
0	1	2	3	4	#Dim
density	1	$\frac{\pi}{\sqrt{12}} \approx 0.9068$	$\frac{\pi}{\sqrt{18}} \approx 0.7404$	$\frac{\pi^2}{16} \approx 0.6168$	

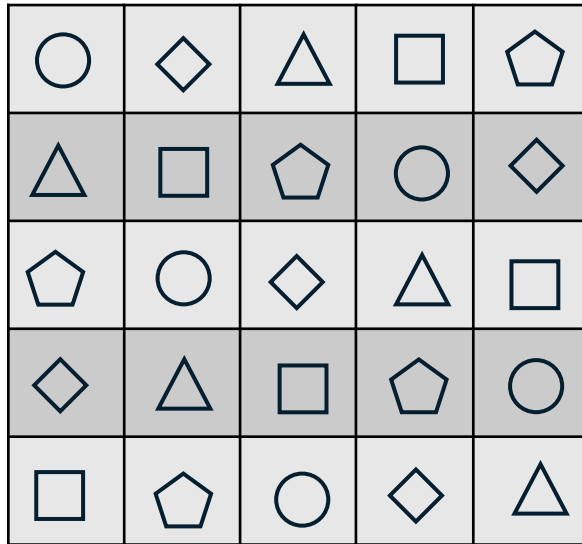
Coded Aperture Design Strategy

Temporal sampling



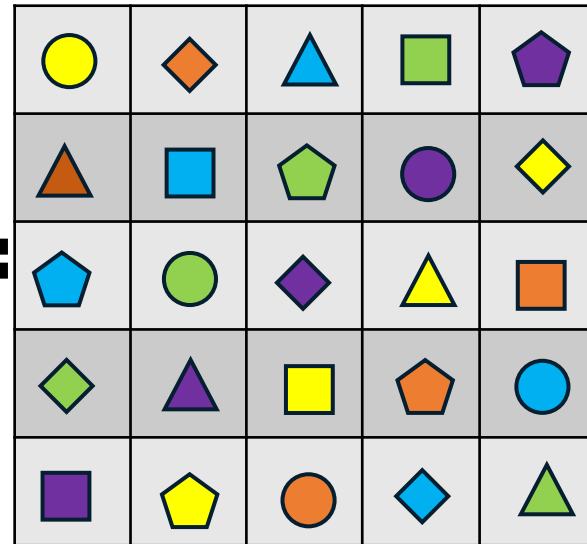
Army regiments

Spectral sampling



Army ranks


























Spectral-video sampling



Leonhard Euler puzzle

Coded Aperture Design Strategy

Spectral-video sampling

Leonhard Euler puzzle

Frame 1



Frame 2



Frame 3



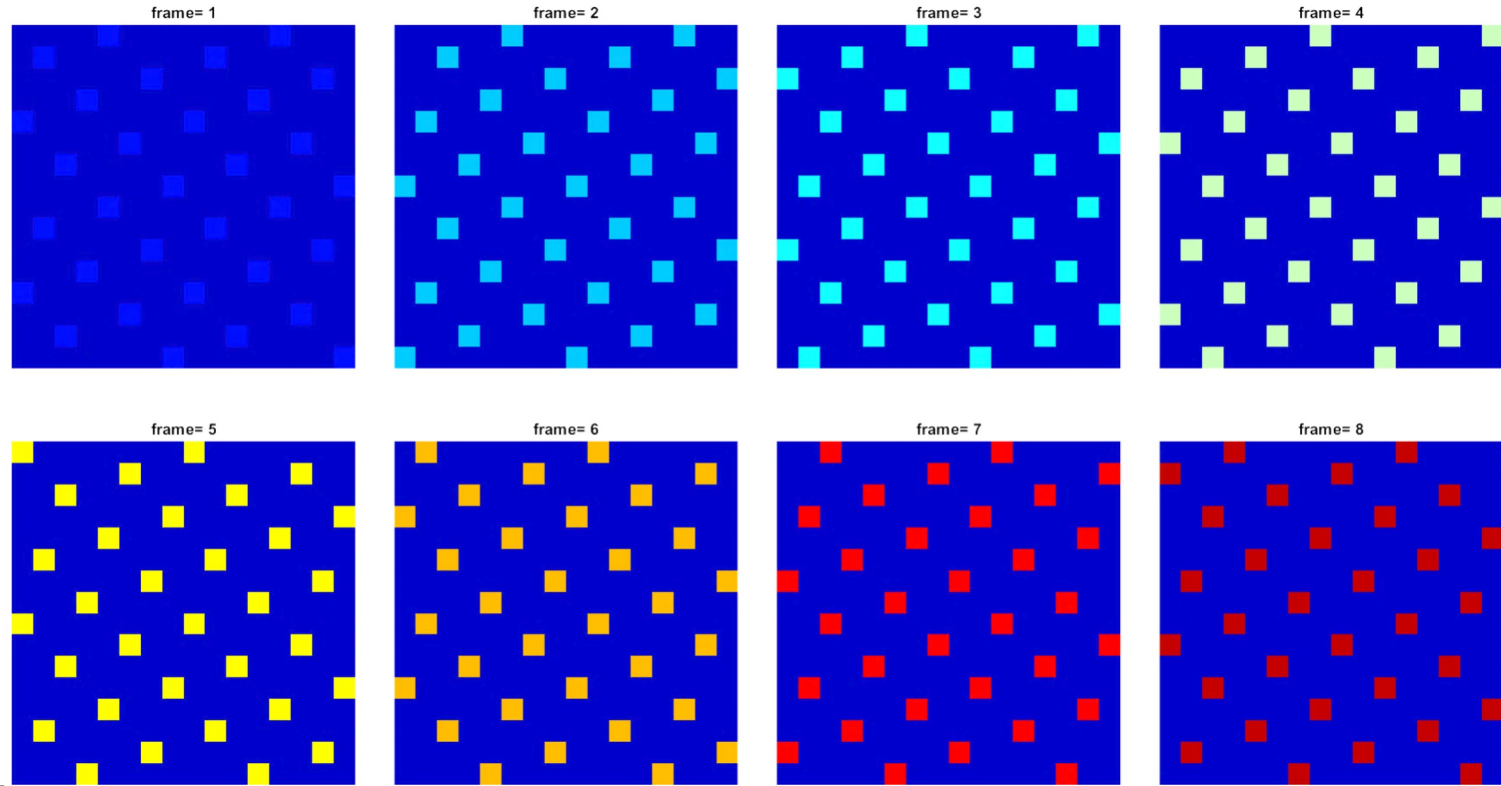
Frame 4



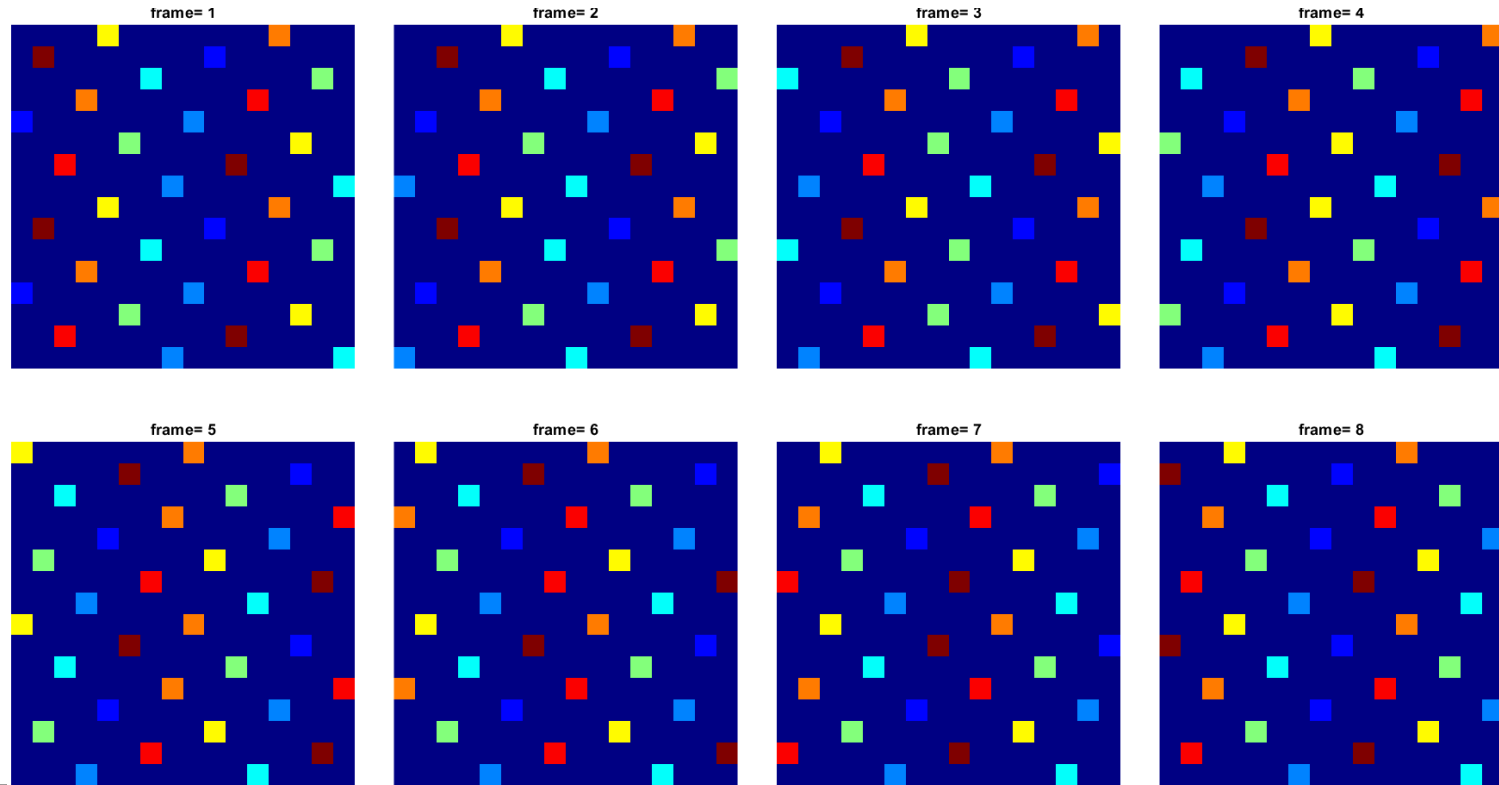
Frame 5



Temporal sampling

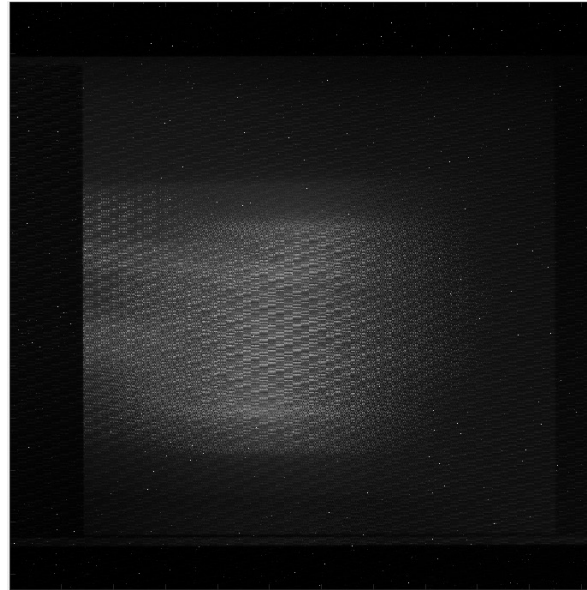


Spectral-video sampling



Spectral-Video Measurement

Snapshot measurement



1128 x 1128

Reconstruction Results

Spectral-video Groundtruth



1128 x 1128 x 16 x 16

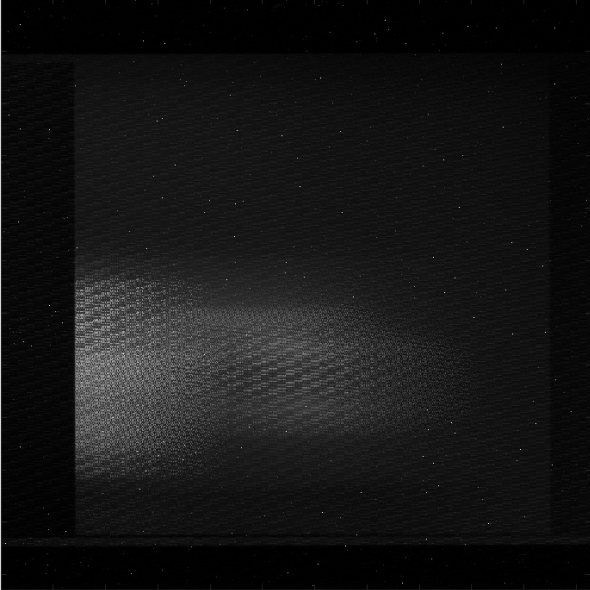
Spectral-video reconstruction



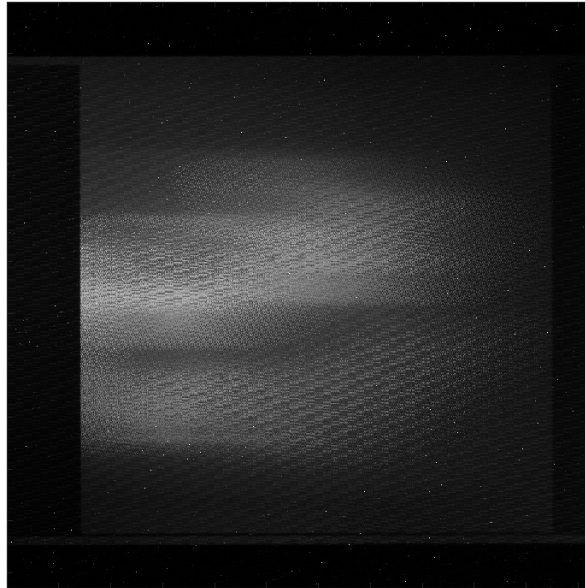
PSNR 26.96 dB, SSIM 0.79, SAM 0.24

Spectral-Video Measurement of 3 different Scenes

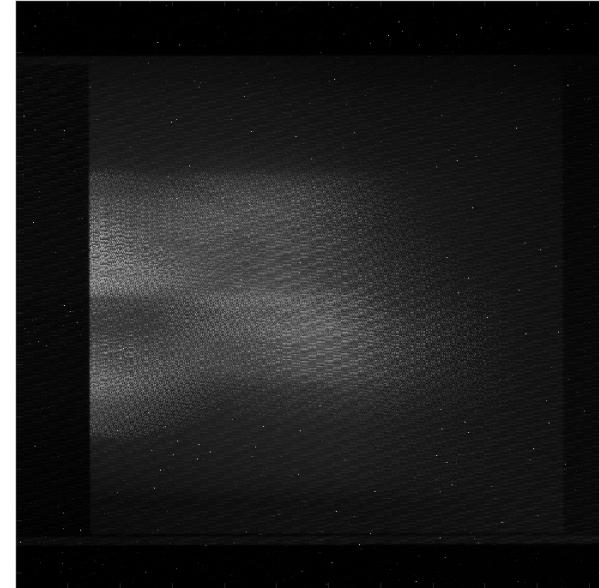
Scene 1



Scene 2

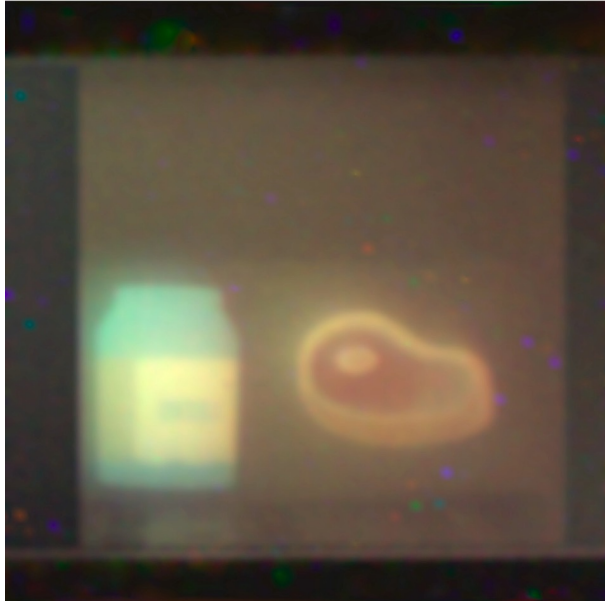


Scene 3



Reconstruction Results

Reconstruction Scene 1



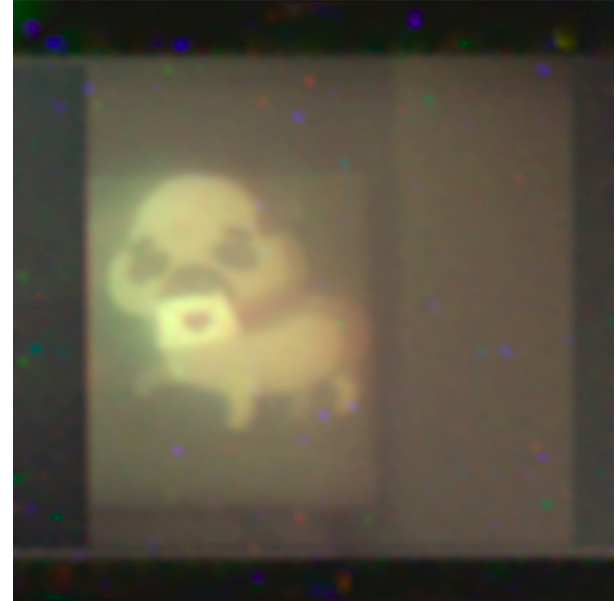
PSNR 28.02 dB, SAM 0.25

Reconstruction Scene 2



PSNR 28.02 dB, SAM 0.22

Reconstruction Scene 3

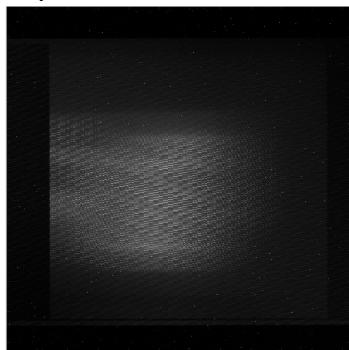


PSNR 27.07 dB, SAM 0.23

Conclusions

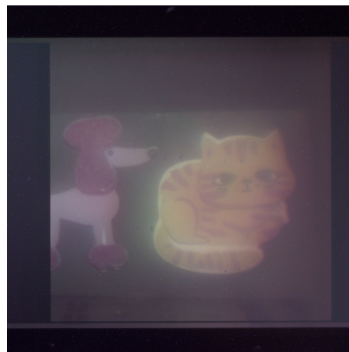
- We introduced a novel **compressive spectral-video sensing** approach that exploits optimal sphere packing.
- Our approach is able to accurately recover a spectral video from a **single snapshot**.
- The proposed approach obtains image reconstruction quality up to 26.96 [dB] of PSNR and 0.24 of SAM.

Compressive measurement



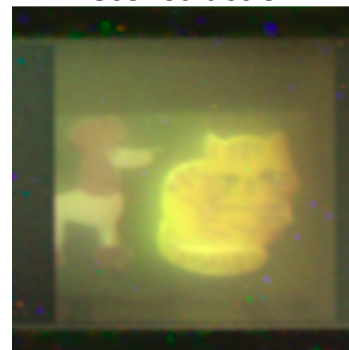
1128 x 1128

Groundtruth



1128 x 1128 x 16 x 16

Reconstruction



PSNR 26.96 dB, SAM 0.24


Thank you!

<https://nelson-diaz.com/>



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ANID FONDECYT Postdoctorado 3230489.



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