Implementation of Adaptive Colored Coded Aperture by Gradient Thresholding Algorithm

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Introduction

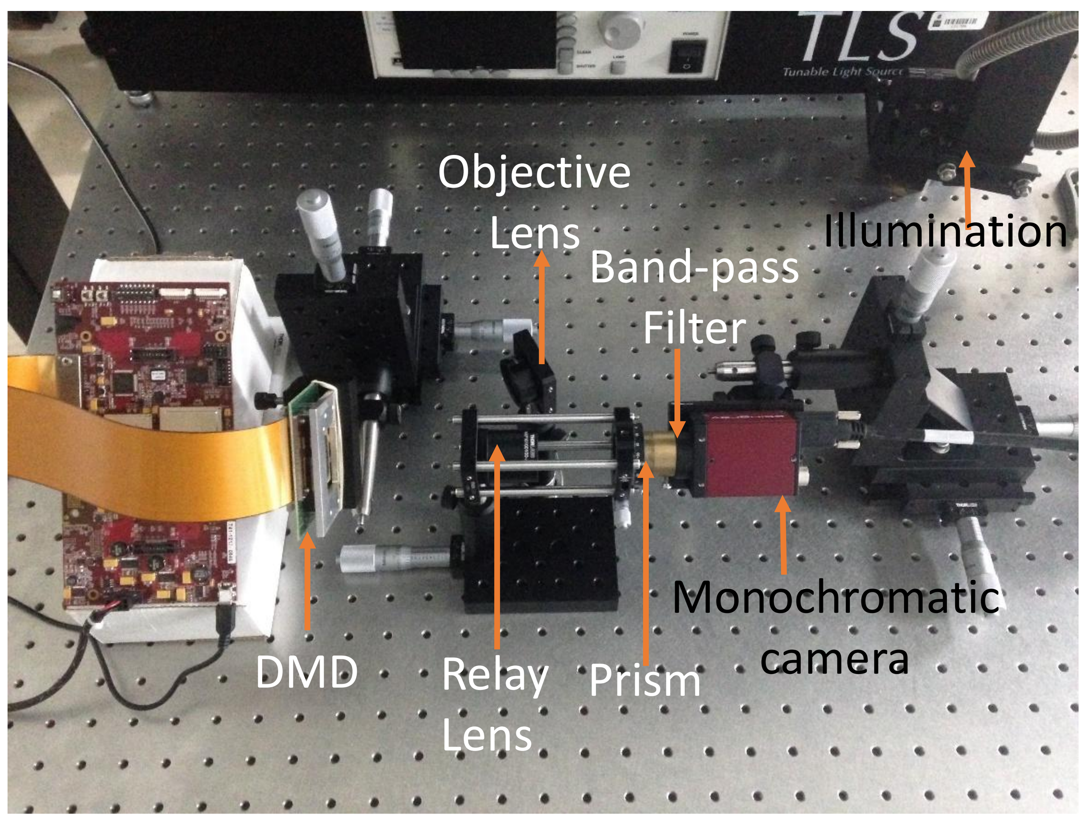

Figure 1: Implementation in laboratory

Objectives

This paper implements the adaptive colored coded apertures for compressive spectral imaging.

Background

The discrete model of the C-CASSI:

$$Y_{ij}^{\ell} = \sum_{k=0}^{L-1} F_{i(j-k)k} T^{\ell}_{i(j-k)k} + \omega_{ij}, \quad (1)$$

where $Y_{i,j}$ is the $(i,j)^{th}$ measurement. The size of the detector is $N \times M$. The data cube F is $N \times N \times L$ and ω_{ij} is the white noise. To improve the quality of image reconstruction it is possible to capture multiple snapshot. The compressive measurements for the multiple snapshot is given by

$$\mathbf{y}^{\ell} = \mathbf{H}\mathbf{f} + \omega, \quad (2)$$

where $\mathbf{y}^{\ell}$ is ℓ^{th} compressive measurements, $\mathbf{H}$ is the measurement matrix and $\mathbf{f} = \boldsymbol{\Psi}\boldsymbol{\theta}$ is the data cube. $\mathbf{f}$ can be recovered by solving

$$\hat{\mathbf{f}} = \boldsymbol{\Psi}(\underset{\boldsymbol{\theta}}{\text{argmin}} \|\mathbf{y} - \mathbf{H}\boldsymbol{\Psi}\boldsymbol{\theta}\|_2 + \tau\|\boldsymbol{\theta}\|_1) \quad (3)$$

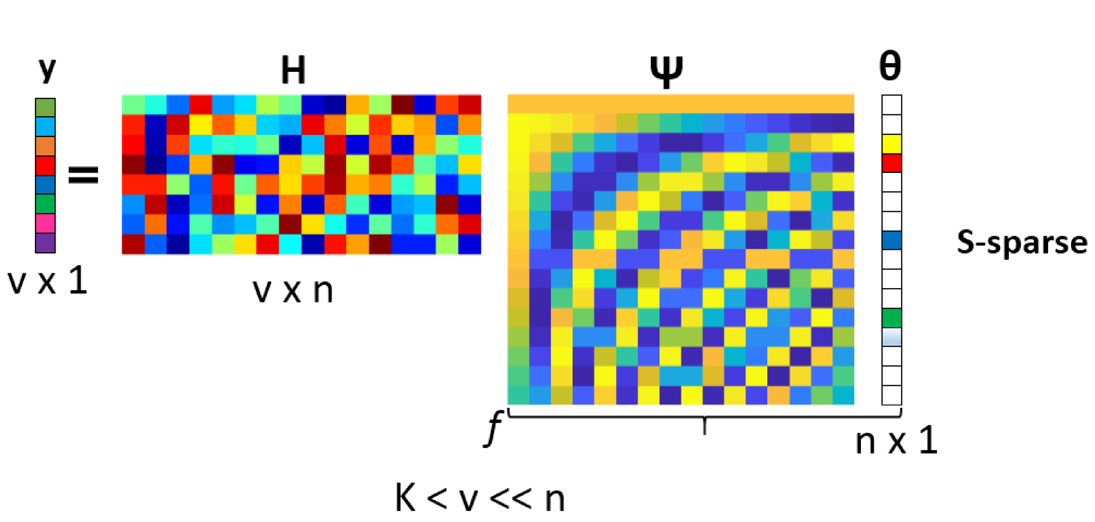

Figure 2: Basic scheme of compressive sensing.

Methods

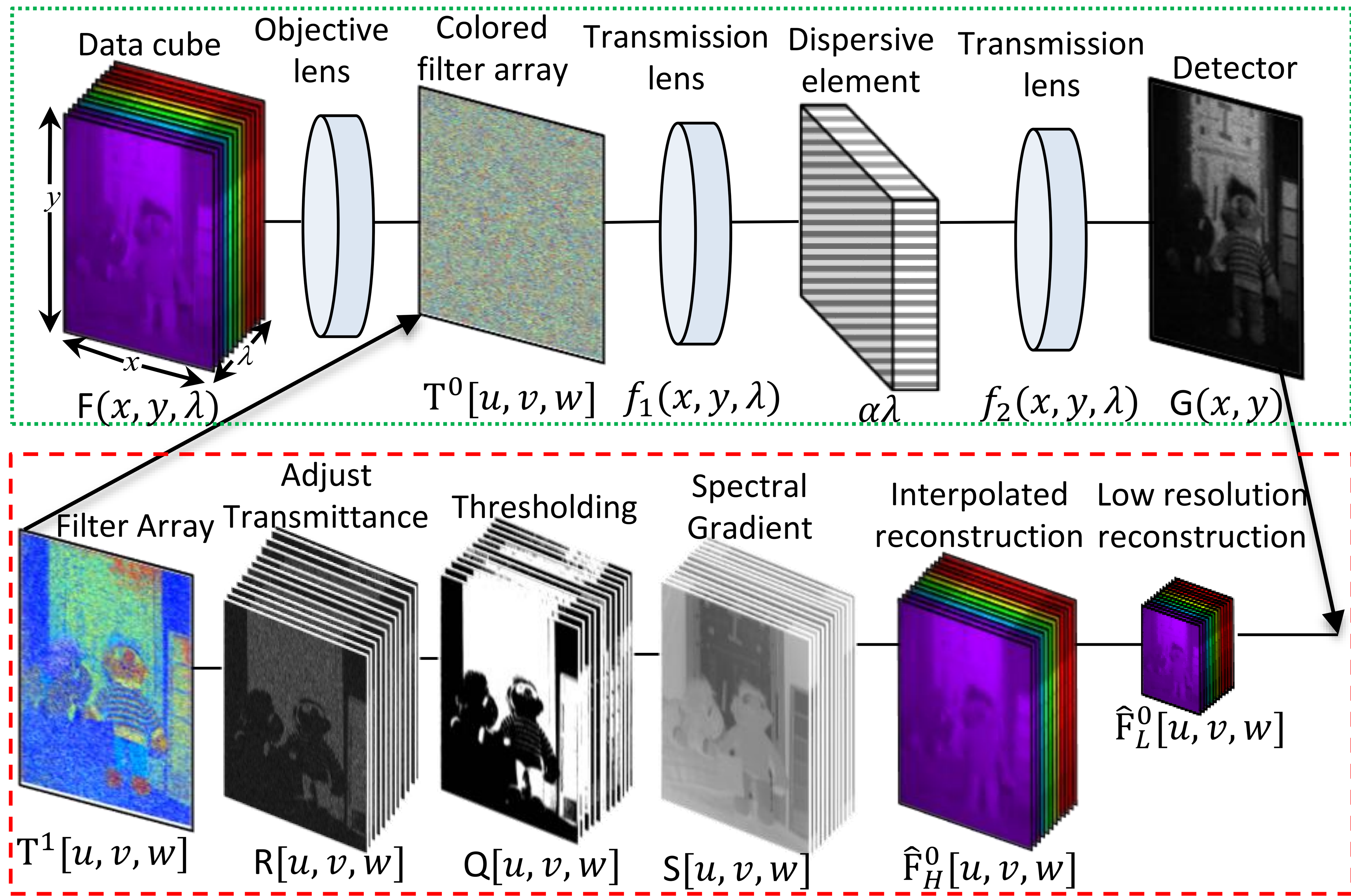

Figure 3: Sketch of C-CASSI. The red dashed line represents the GTA algorithm.

Algorithm 1 Gradient thresholding algorithm

Require: $\mathbf{y}^0, \mathbf{H}^0$,
Ensure: $\hat{\mathbf{f}}$
function GTA($\mathbf{y}^0, \mathbf{H}^0$)
  for $\ell \leftarrow 0, K-1$ **do**
    $\hat{\mathbf{f}}_L^{\ell} \leftarrow \boldsymbol{\Psi}_L(\text{argmin}_{\boldsymbol{\theta}_L} \|\mathbf{y} - \mathbf{H}_L\boldsymbol{\Psi}_L\boldsymbol{\theta}_L\|_2^2 + \tau\|\boldsymbol{\theta}_L\|_1$ ▷ Low-resolution
    $\hat{\mathbf{f}}_H^{\ell} \leftarrow \mathbf{P}\hat{\mathbf{f}}_L^{\ell}$ ▷ Interpolation
    $\mathbf{s}^{\ell} \leftarrow \mathbf{B}^2\hat{\mathbf{f}}_H^{\ell}$ ▷ Compute gradient
    $\mathbf{q}^{\ell} \leftarrow (\mathbf{s}^{\ell} \preceq \mathbf{0})$ ▷ Thresholding
    $\mathbf{r}^{\ell} \leftarrow \mathbf{q}^{\ell} \odot \mathbf{r}_d^{\ell} + (\mathbf{1} - \mathbf{q}^{\ell}) \odot \mathbf{r}_u^{\ell}$, ▷ Transmittance
    for $j \leftarrow 0, N^2L-1$ **do**
      $k = \lfloor j/N^2 \rfloor, l = j \mod N^2$
      $(\mathbf{t}_k^{\ell})_l \leftarrow t_j^{\ell}$ ▷ Rearrange $\mathbf{r}$
      for $i \leftarrow 0, KV-1$ **do**
        if $i - \ell_i V = j - k_j N'$ **then**
          $(\mathbf{H}_i)_j \leftarrow (\mathbf{r}_{k_j}^{\ell_i})_{i-\ell_i v - k_j N}$ ▷ Compute $\mathbf{H}$
        else
          $(\mathbf{H}_i)_j \leftarrow 0$
    $\mathbf{y}^{\ell+1} \leftarrow \mathbf{H}^{\ell+1}\mathbf{f}$ ▷ Next snapshot
  return $\hat{\mathbf{f}} \leftarrow \boldsymbol{\Psi}(\text{argmin}_{\boldsymbol{\theta}} \|\mathbf{y} - \mathbf{H}\boldsymbol{\Psi}\boldsymbol{\theta}\|_2 + \tau\|\boldsymbol{\theta}\|_1$

Results

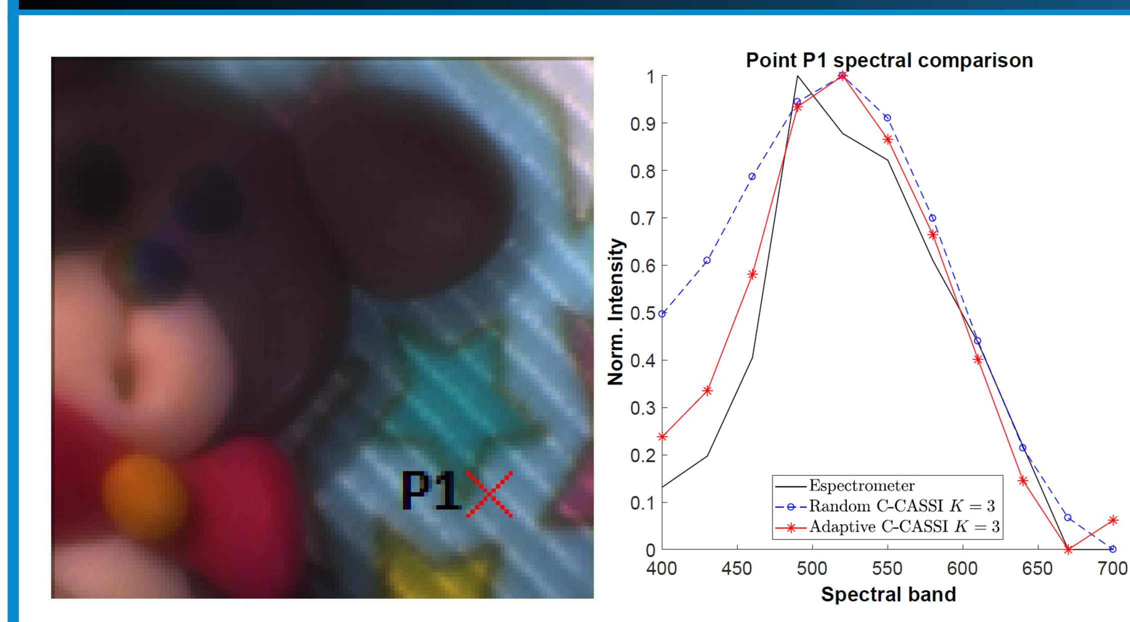

Figure 4: Bear-stars scene, multispectral database, $N \times N \times L$, where $N = 512$, and $L = 12$.

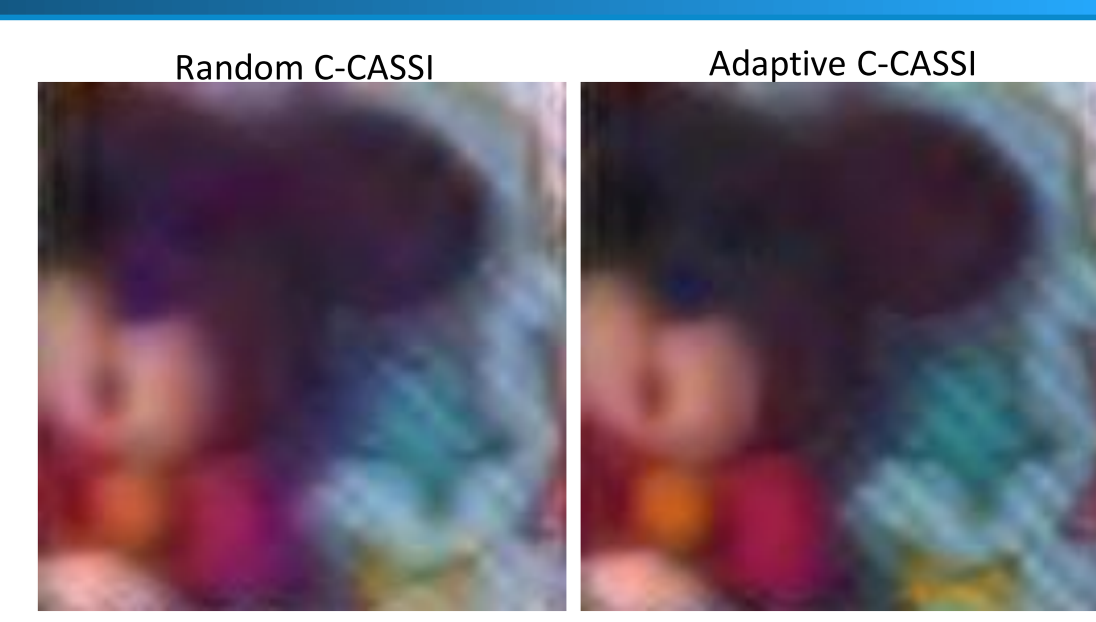

Figure 5: RGB comparison random C-CASSI and adaptive C-CASSI, number of snapshots $K = 3$.

Conclusion

Quality of image reconstruction of the adaptive C-CASSI is compared with the random C-CASSI. The proposed method improves the quality of reconstruction in up to **2 dB**.

Future Research

In the future the adaptive colored filter array will be optimized improving the quality of image reconstruction. The approach will be test with other compressive spectral imaging architectures.

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References

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[2] Nelson Diaz, Hoover Rueda, and H. Arguello. High-dynamic range compressive spectral imaging by grayscale coded aperture adaptive filtering. *Ingeniería e Investigación*, 35(3):53–60, 2015.