Motion Blur Prior

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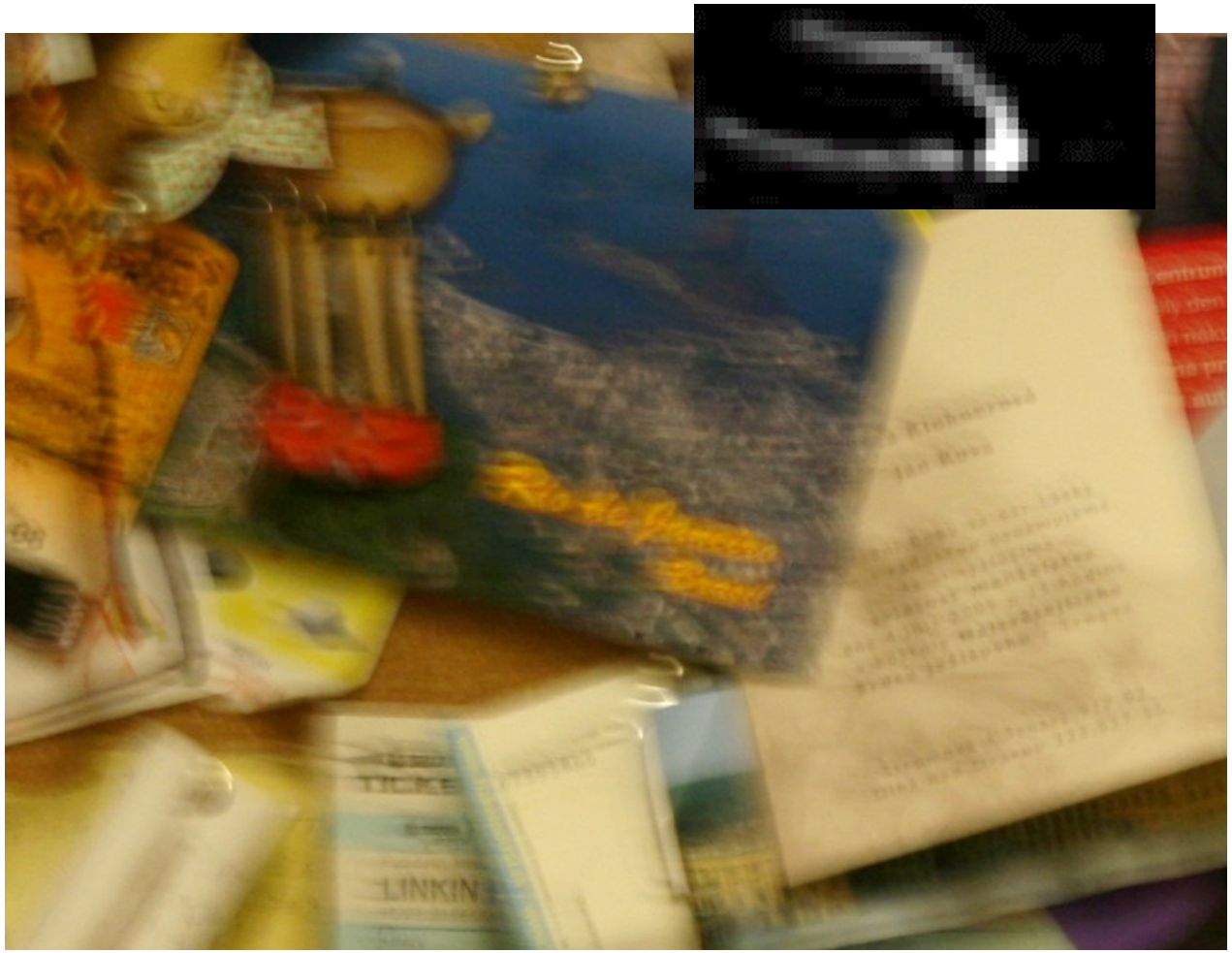
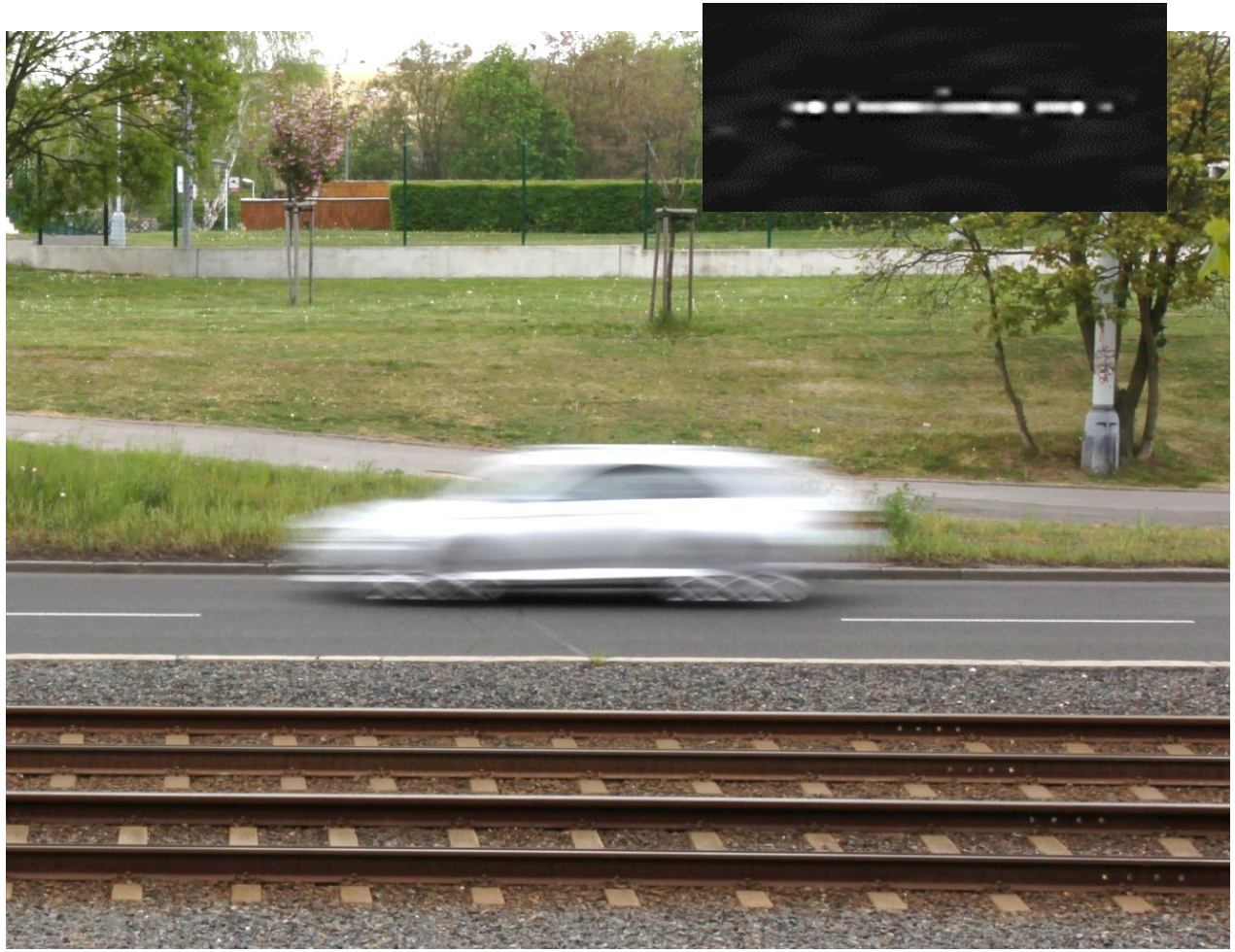
Motion Blur

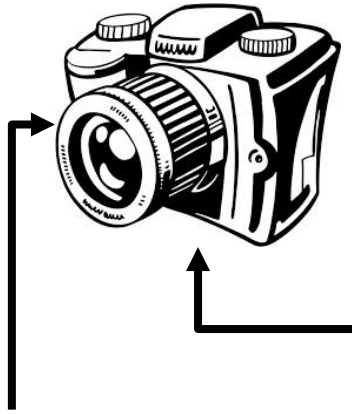


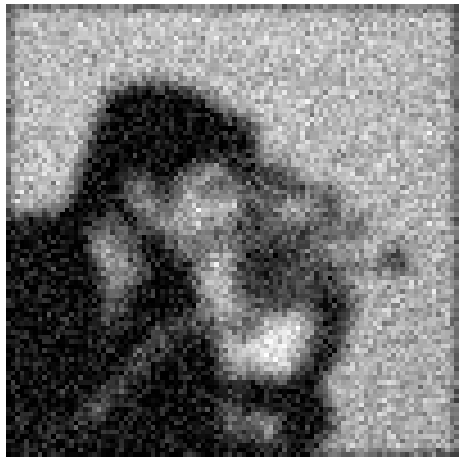
Camera motion



Object motion

Image Degradation Model





original image

blur

noise

acquired image

$$D(\quad u \quad , \quad h \quad) \qquad + \qquad n \qquad = \quad z$$

e.g. convolution $h * u$

Deblurring

$$\min_{u,h} \frac{\gamma}{2} \|D(h,u) - z\|^2$$

Data term

- Coupling of u and h → infinite number of solution

Deblurring Regularization

$$\min_{u,h} \frac{\gamma}{2} \|D(h,u) - z\|^2 + \phi(u) + \psi(h)$$

Data term

Image regularization

- Coupling of u and h → infinite number of solution
- Image gradient is sparse irrespective of the content $\phi(u) = \sum_i |\nabla u_i|^p$

Deblurring Regularization

$$\min_{u,h} \frac{\gamma}{2} \|D(h,u) - z\|^2 + \phi(u) + \psi(h)$$

Data term

Image regularization

Blur regularization

- Coupling of u and h → infinite number of solution

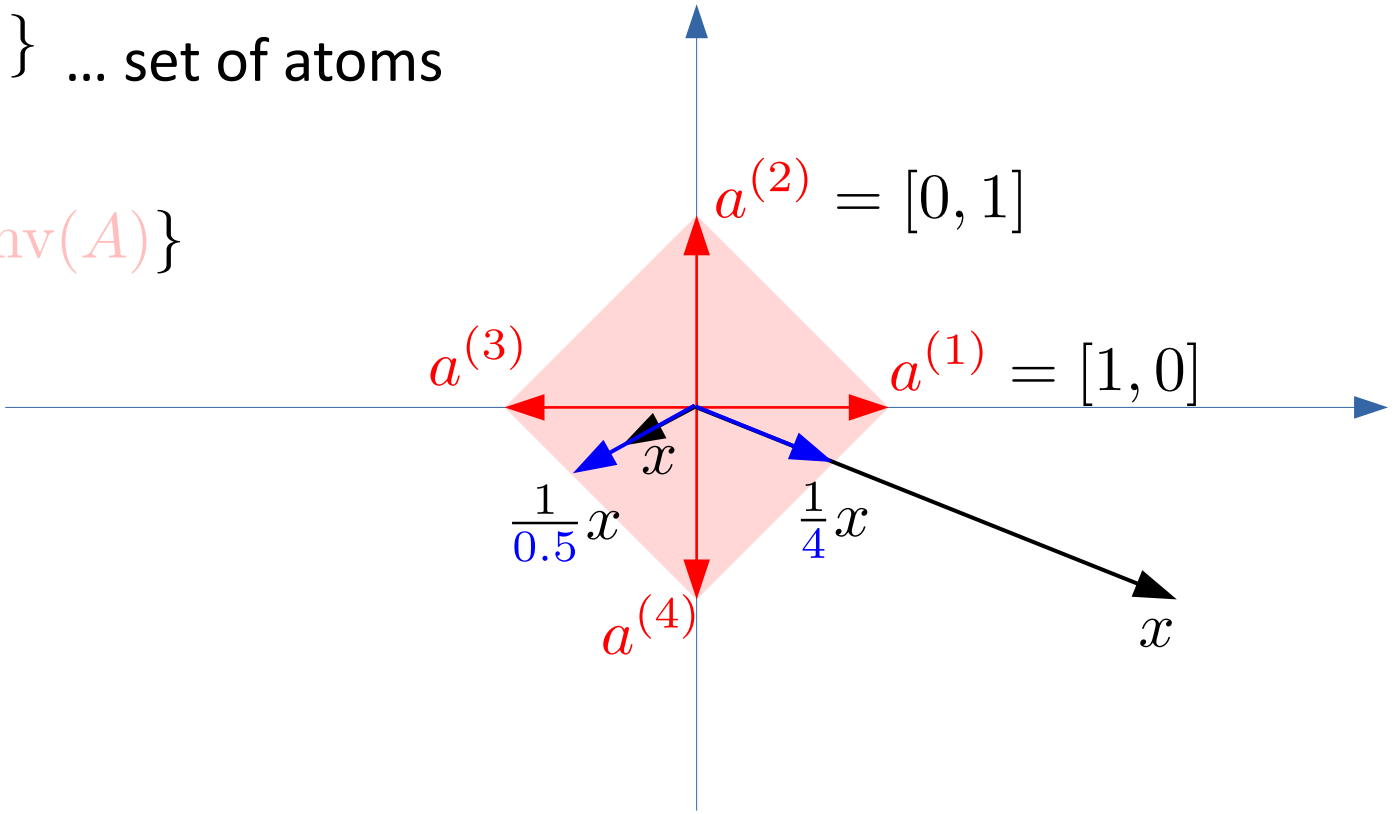
- Less informative priors:

  non-negativity, preserve energy → $h \in S := \{h_i \geq 0, \sum_i h_i = 1\}$

Atomic Norm

$A := \{a^{(1)}, a^{(2)}, a^{(3)}, a^{(4)}\}$ … set of atoms

$\|x\|_A := \inf\{t > 0 \mid \frac{1}{t}x \in \mathrm{conv}(A)\}$



Atomic norm with this A implements the ℓ_1 norm.

Different atoms give rise to different norms, e.g. nuclear, infinity norm …

Linear Program

Advantage: Atomic norm can be implemented as a LP problem

$$\|x\|_A = \min_c \sum_i c_i$$

subject to $x = \sum_i c_i a^{(i)},\ c_i \geq 0$

Proposed Curve Prior

- Atoms are curve segments

$$A := \left\{ \right.$$  $$\left. \right\}$$

$$\psi(h) = \begin{cases} \alpha \|h\|_A, & h \in S := \{h_i \geq 0, \sum_i h_i = 1\}; \\ +\infty, & \text{otherwise} \end{cases}$$

Blind Deblurring with Curve Prior

$$\min_{h,u} \frac{\gamma}{2}\|D(h,u) - z\|^2 + \phi(u) + \psi(h)$$

$$\min_{h,c,u} \frac{\gamma}{2}\|D(h,u) - z\|^2 + \phi(u) + \chi_S(h) + \alpha \sum_i c_i$$

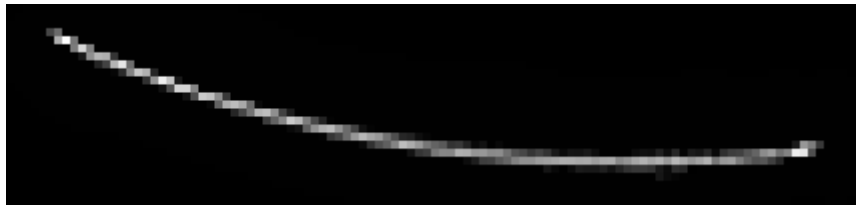
$$\text{s.t.} \quad h = \sum_i c_i a^{(i)},\ c_i \geq 0$$

Indicator function:

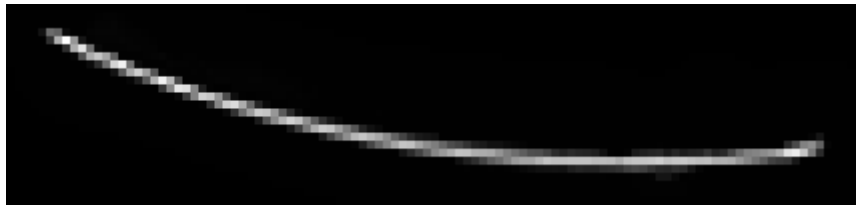
$$\chi_S(h) = \begin{cases} 0, & h \in S := \{h_i \geq 0, \sum_i h_i = 1\}; \\ +\infty, & \text{otherwise} \end{cases}$$

Performance w.r.t. Noise

50dB

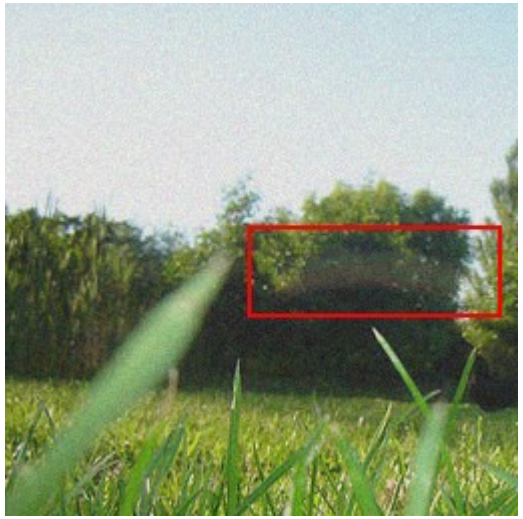


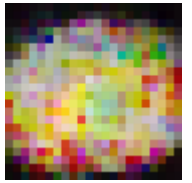
Std. prior



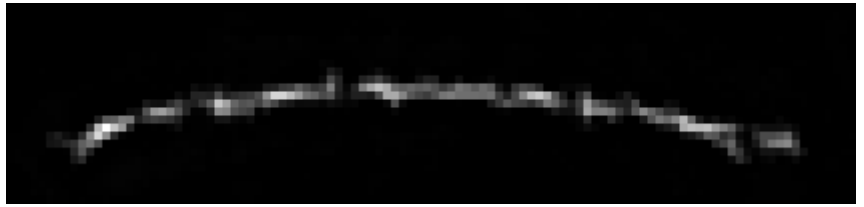
Curve prior

20dB



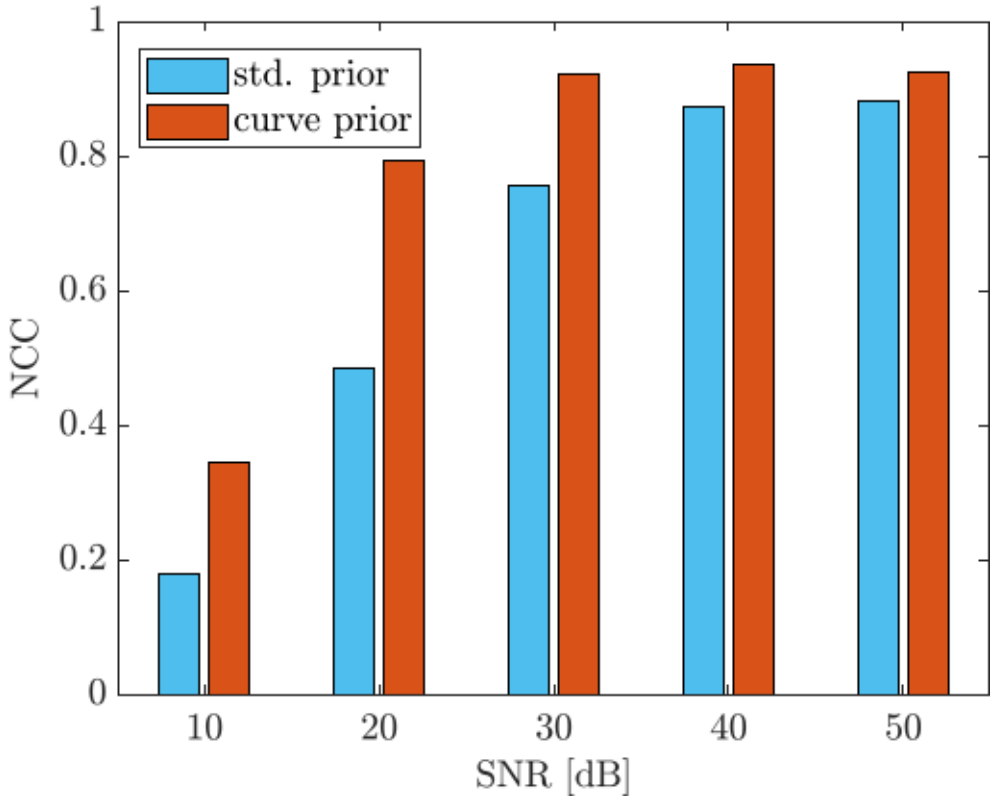


Std. prior



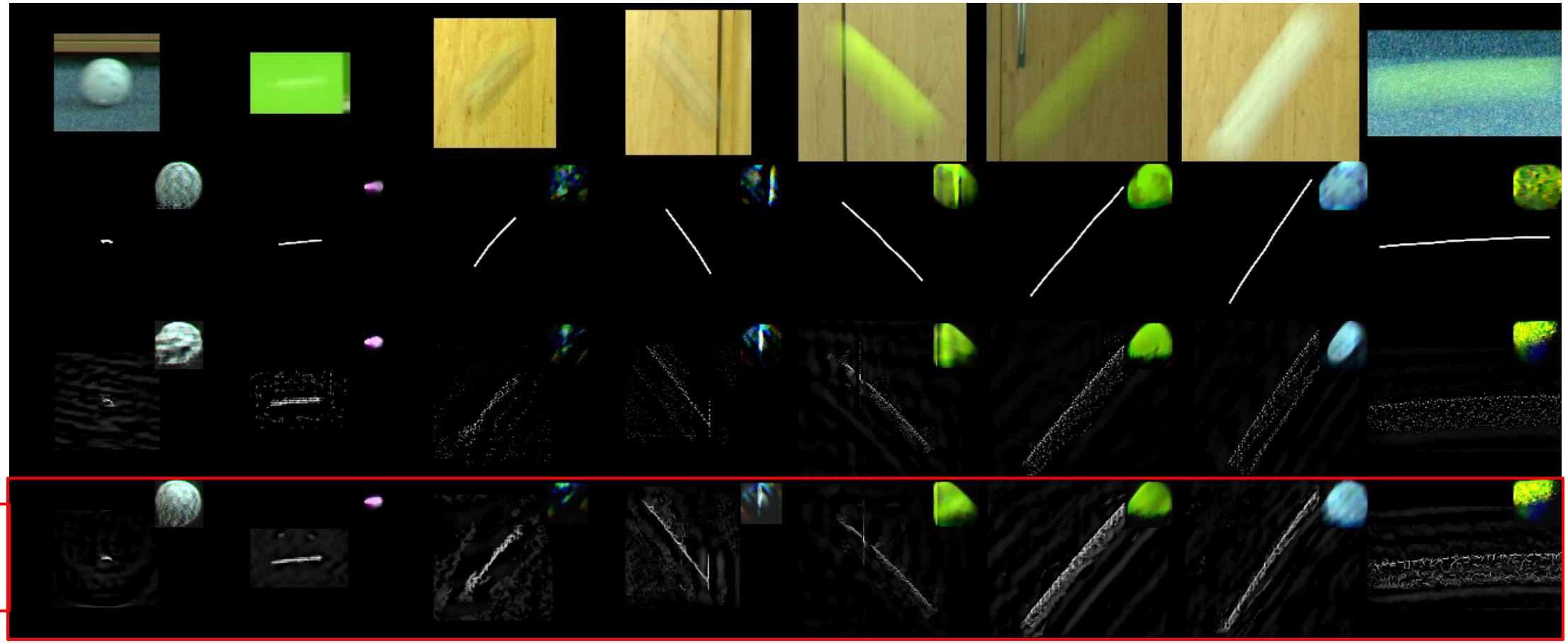
Curve prior

Performance w.r.t. Noise



Real-data examples

Fast-Moving-Object Dataset



Thank you
for your attention

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code: zoi.utia.cas.cz/curveprior