Accurate Recovery of a Specularity from a few Samples of the Reflectance Function

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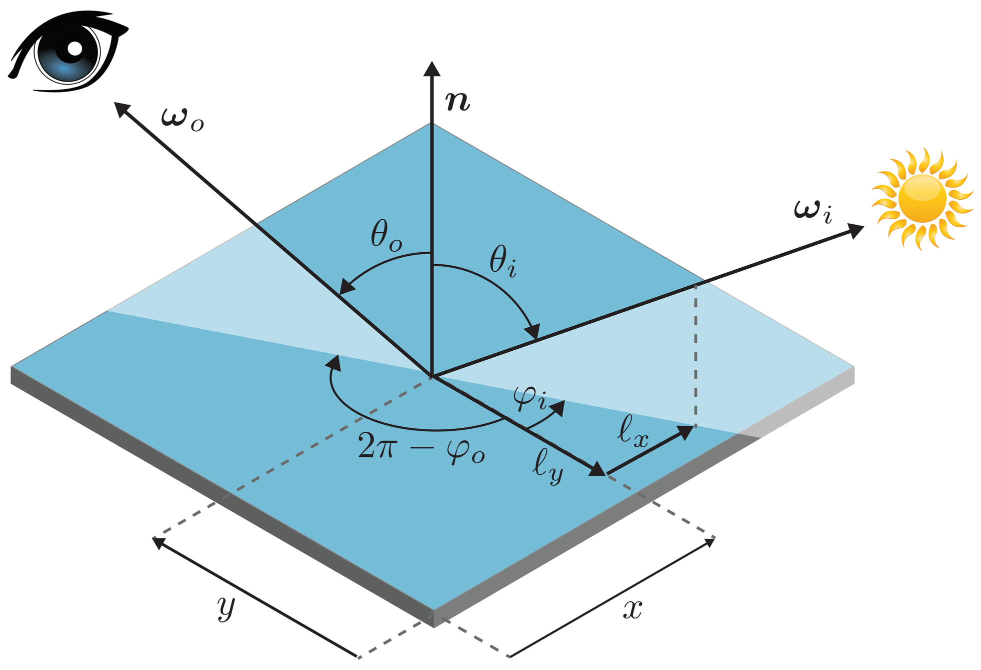
Problem statement

Acquire the specularity of reflectance functions with a few samples

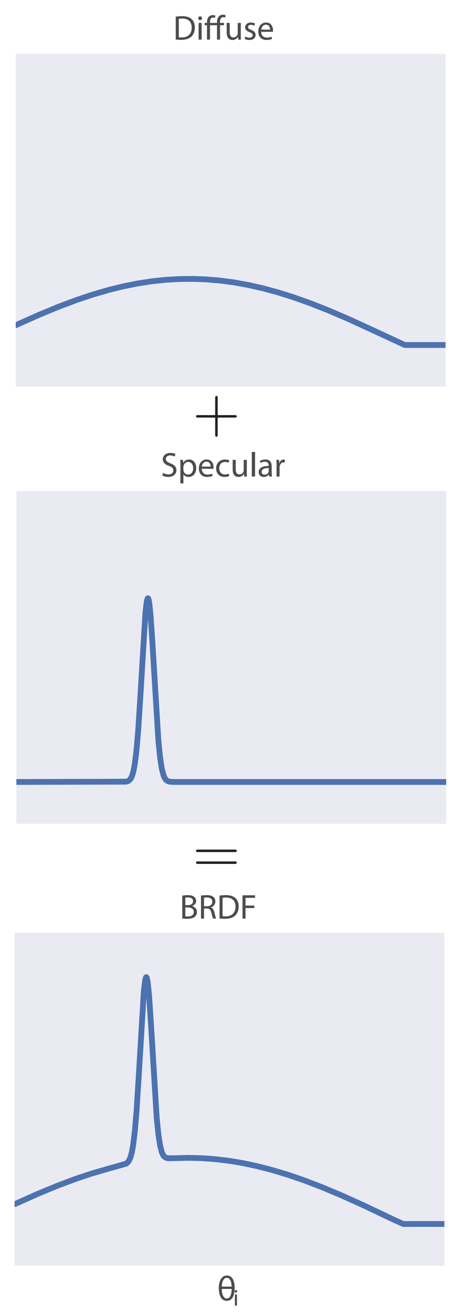
Background

Bidirectional Reflectance Distribution Function (BRDF): $\rho(\boldsymbol{\omega}_o, \boldsymbol{\omega}_i)$



Symbol	Notation
$\boldsymbol{\omega}_i = (\theta_i, \varphi_i)$	Incident light angle
$\boldsymbol{\omega}_o = (\theta_o, \varphi_o)$	Viewing angle
$\boldsymbol{n}$	Surface normal vector
$L_i(\boldsymbol{\omega})$	Incoming light at angle $\boldsymbol{\omega}$
$L_o(\boldsymbol{\omega})$	Light reflected at angle
(ℓ_x, ℓ_y)	Projection of $\boldsymbol{\omega}_i$ onto the xy plane

BRDF shape



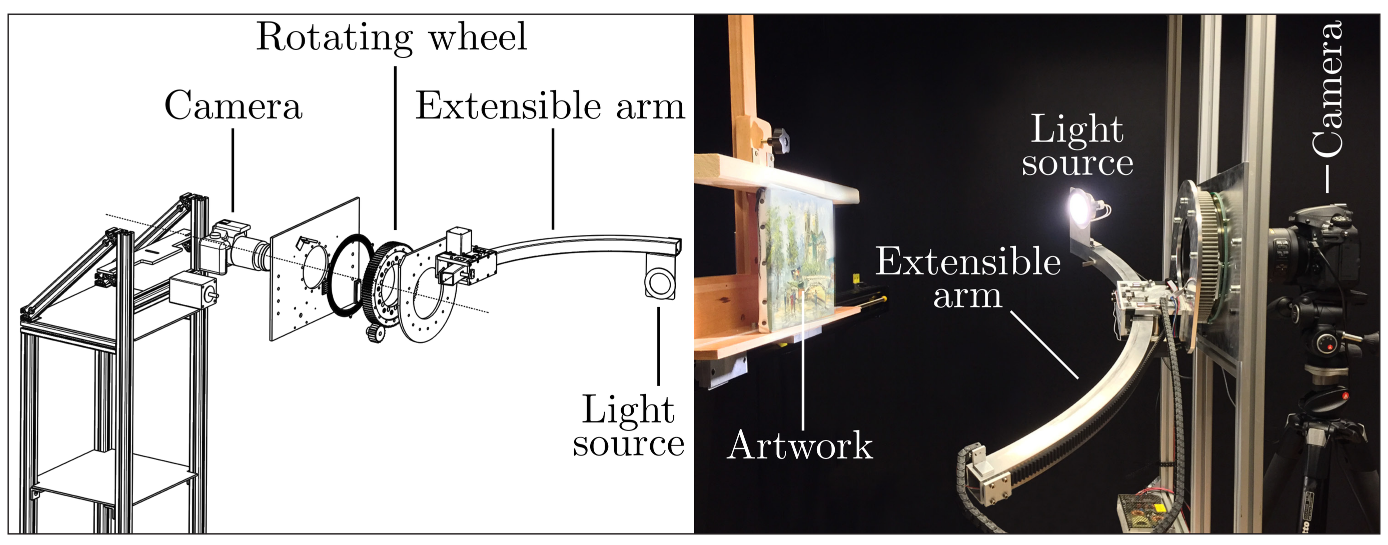
BRDF acquisition

Reflection equation

$$L_o(\boldsymbol{\omega}_o) = \int_{\Omega} L_i(\boldsymbol{\omega}) \rho(\boldsymbol{\omega}, \boldsymbol{\omega}_o) \langle \boldsymbol{n}, \boldsymbol{\omega} \rangle d\boldsymbol{\omega}$$

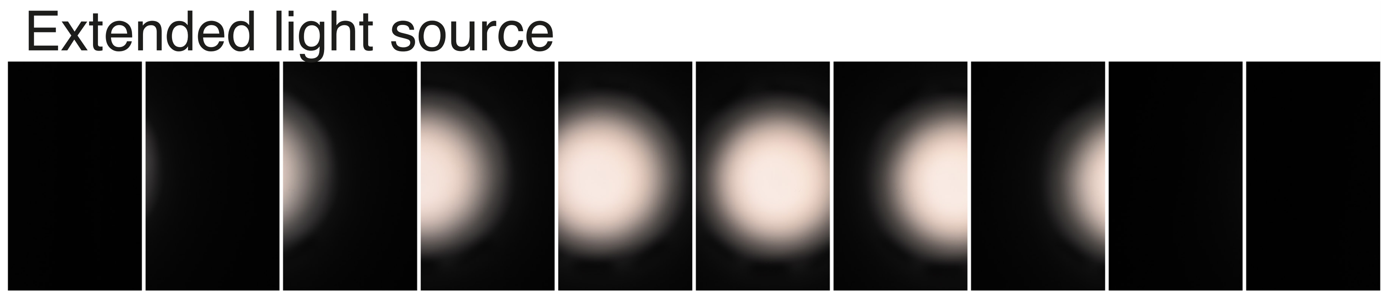
BRDF acquisition

- Take several photographs of an object for different $(\boldsymbol{\omega}_o, \boldsymbol{\omega}_i)$



Pointwise light source

Extended light source



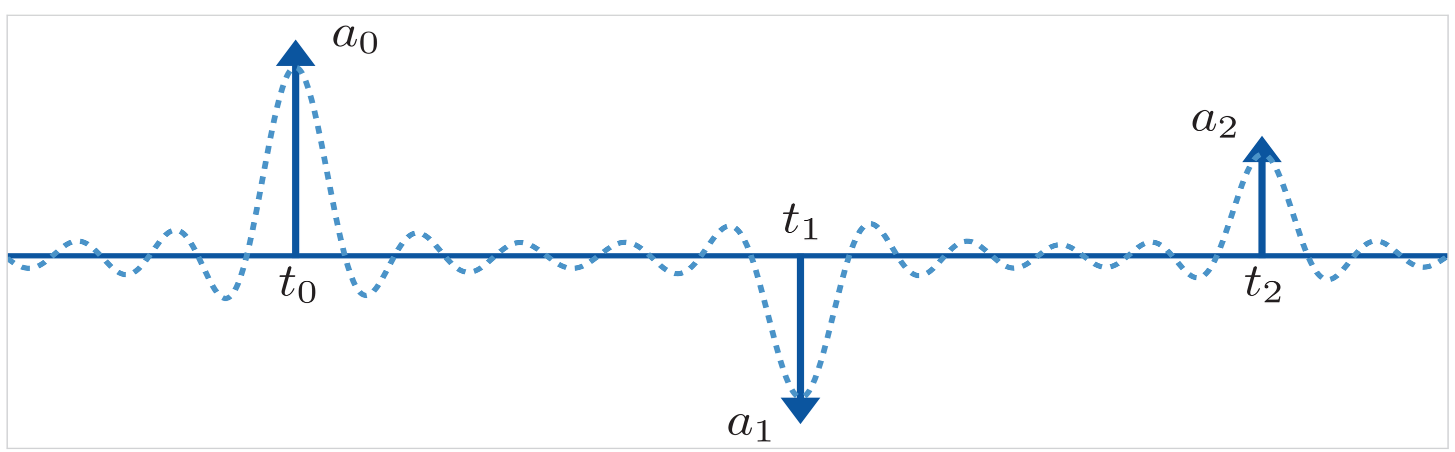
Proposed solution: use finite rate of innovation sampling with extended light and unknown pulse shape

Finite Rate of Innovation (FRI) sampling [1]

Goal: sample and reconstruct signals with a finite number of parameters (innovations)

Example: τ-periodic stream of K Dirac pulses

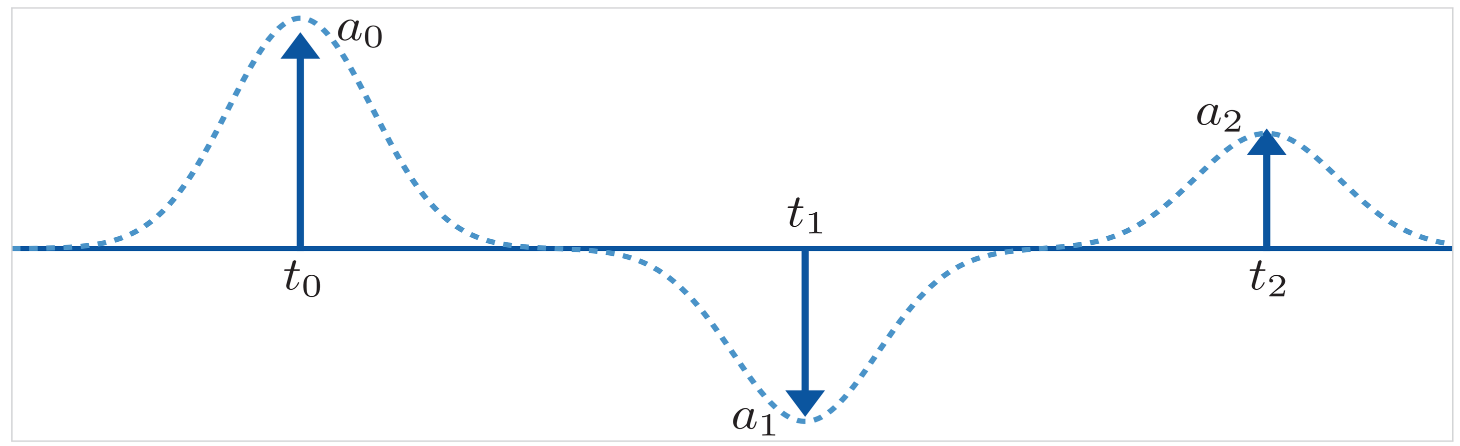
$$X[m] = \frac{1}{\tau} \sum_{k=0}^{K-1} a_k e^{i2\pi t_k m/\tau}, \qquad m \in \mathbf{Z}$$



FRI with unknown sampling kernel

FRI Sampling kernels: Sinc, Gaussian [1], polynomial and exponential reproducing kernels [2]

Proposed model: $X[m] = \frac{1}{\tau} \sum_{k=0}^{K-1} a_k e^{i2\pi t_k m/\tau} \Phi[m], \qquad m \in \mathbf{Z}$ (unknown shape: $\Phi[m]$)



Parameters estimation as in the traditional case

- Find an annihilating filter $A[m]$ for $X[m]$

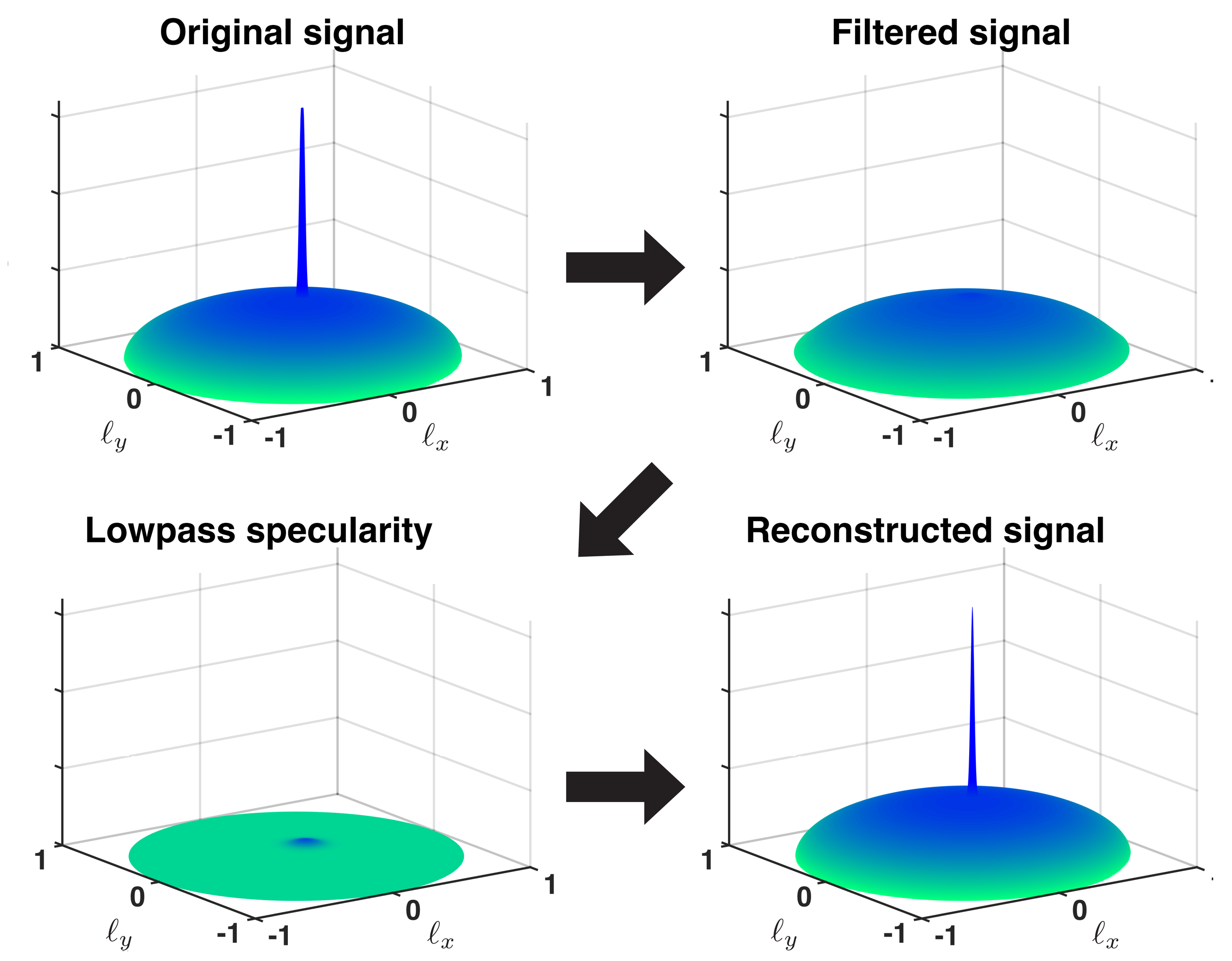
$$(A * X)[m] = 0, \qquad \forall m \in \mathbb{Z}$$

Dirac locations $\{t_k\}_{k=0}^{K-1}$ derived from the roots of $A(z)$

- Amplitudes $\{a_k\}_{k=0}^{K-1}$ estimated by matrix inversion

Assumptions: single pulse, symmetric sampling kernel

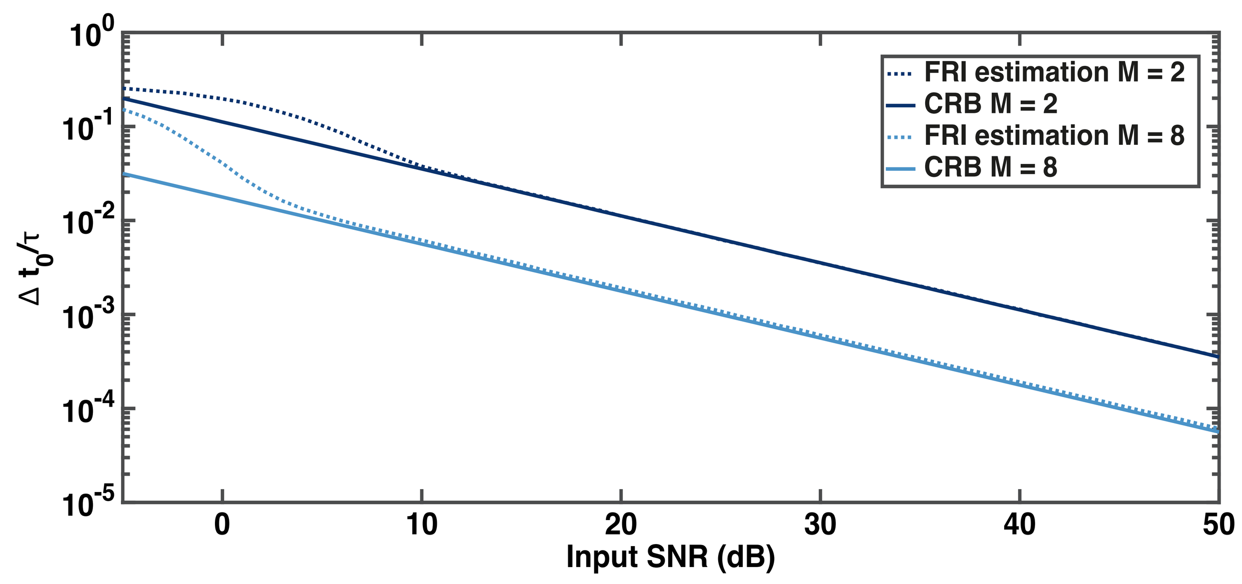
Simulations



- SNR of reconstruction: 52.2 dB

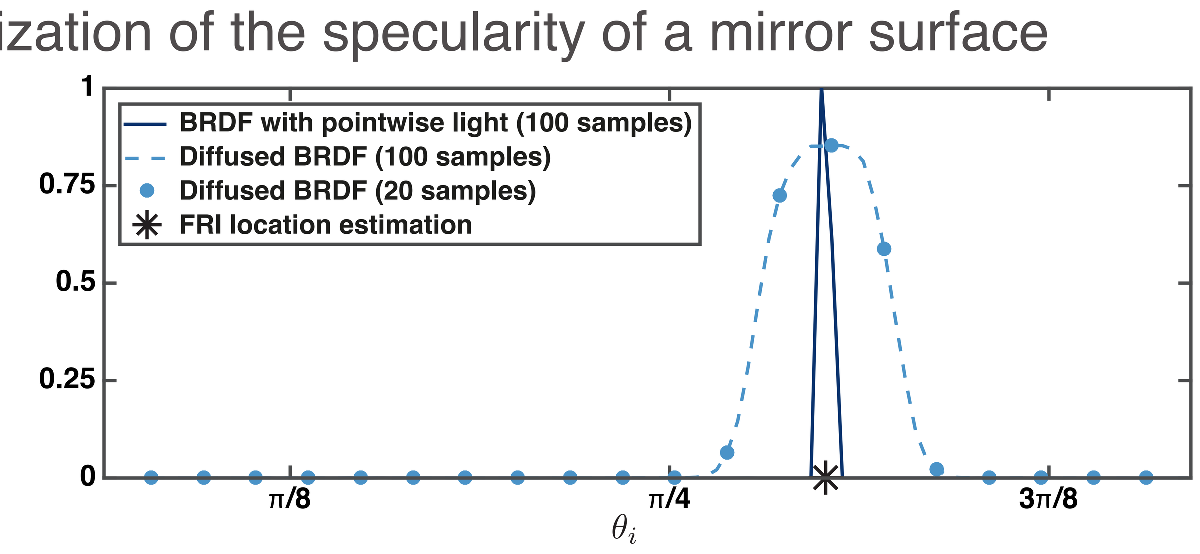
Performance on noisy data

Comparison with Cramér-Rao lower bound



Practical acquisition

Localization of the specularity of a mirror surface



REFERENCES

[1] M. Vetterli, P. Marziliano, and T. Blu, "Sampling Signals with Finite Rate of Innovation," IEEE Trans. on Signal Processing, vol. 17, no. 6, pp. 1417–1428, 2002.

[2] P. L. Dragotti, M. Vetterli, and T. Blu, "Sampling Moments and Reconstructing Signals of Finite Rate of Innovation: Shannon meets Strang-Fix," IEEE Trans. on Signal Processing, vol. 55, no. 5, pp. 1741–1757, 2007.

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