Cardinality-Constrained Texture Filtering

Josiah Manson and Scott Schaefer

Texas A&M University

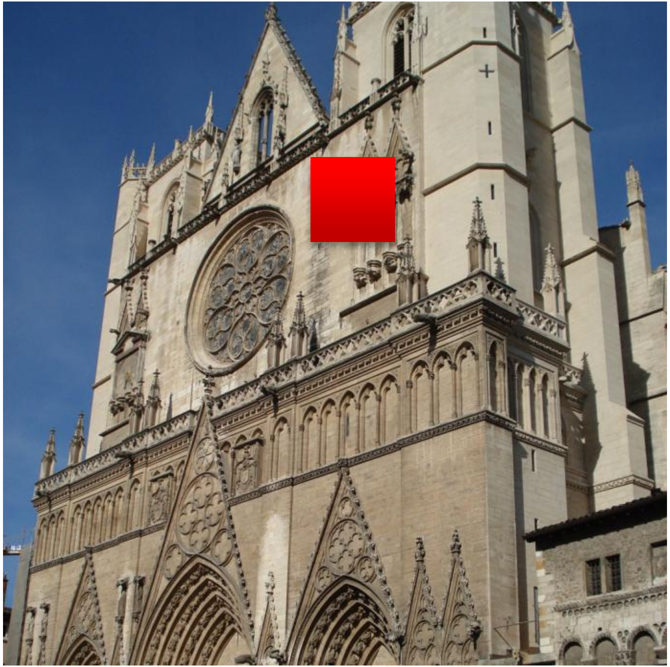
SIGGRAPH2013

Image Sampling

Input

Downsampled

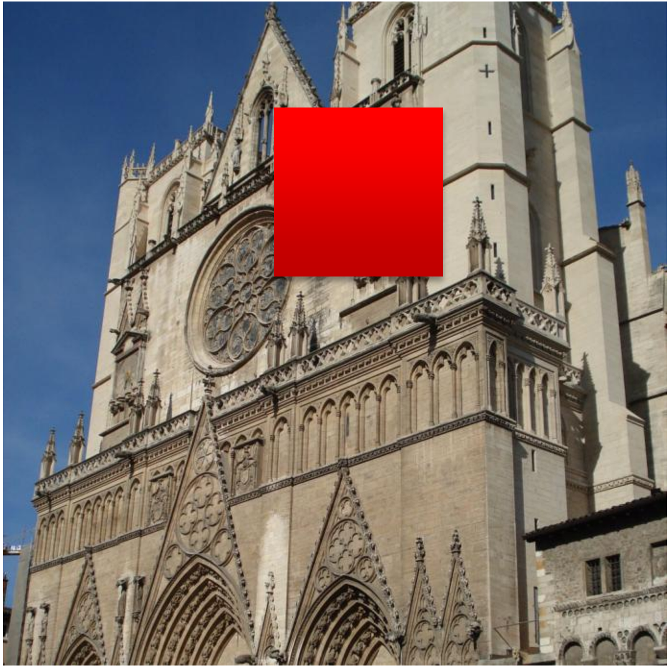
Image Sampling



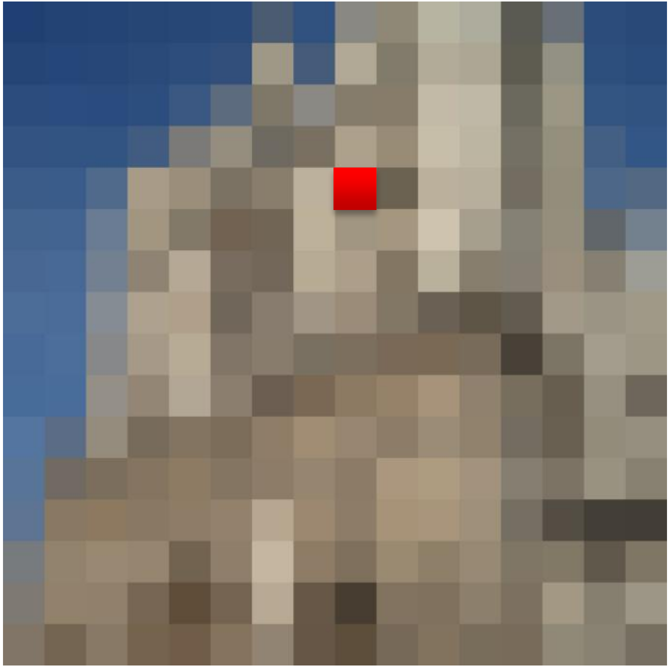
Input

Downsampled

Image Sampling

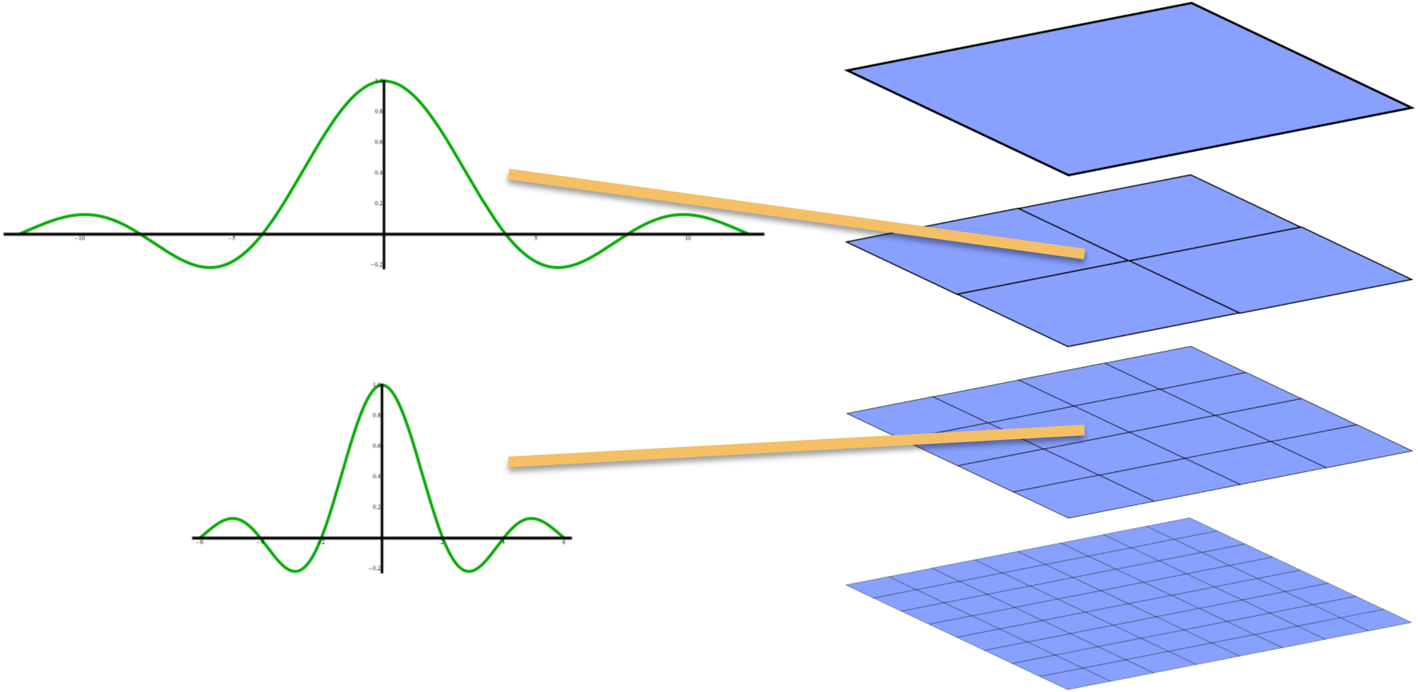


Input

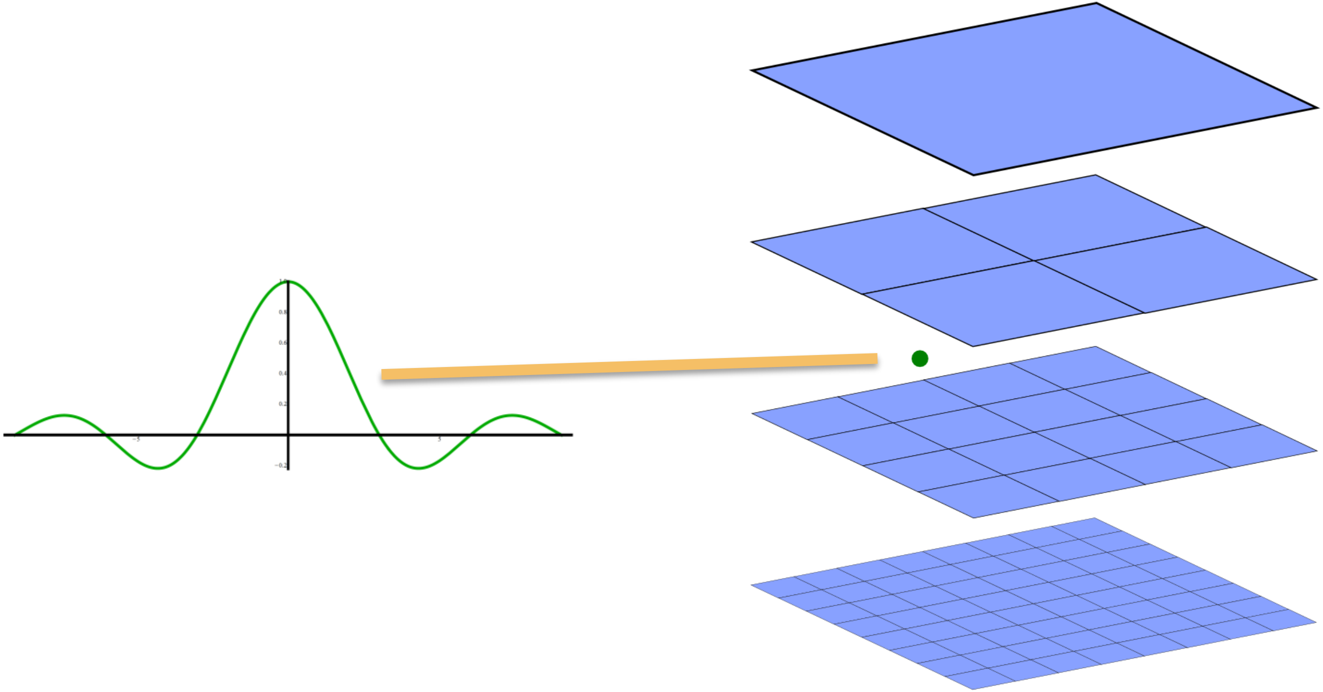


Downsampled

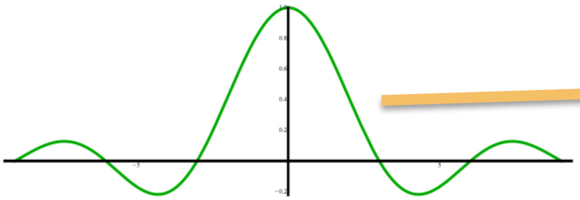
Mipmapping

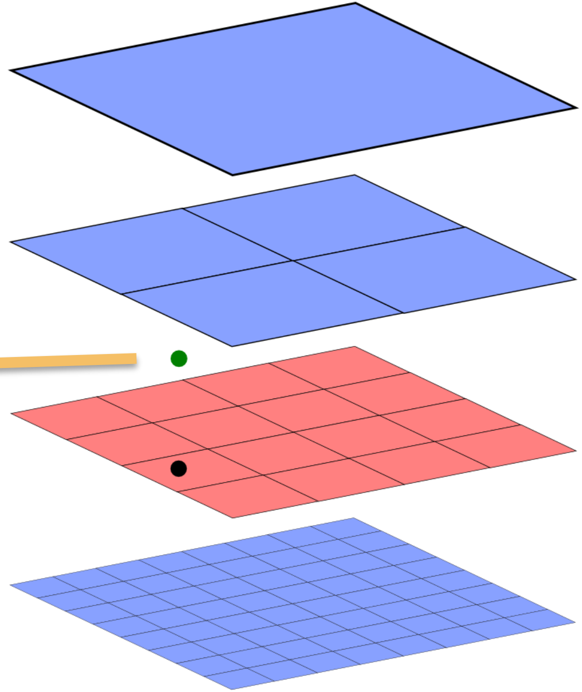


Mipmapping

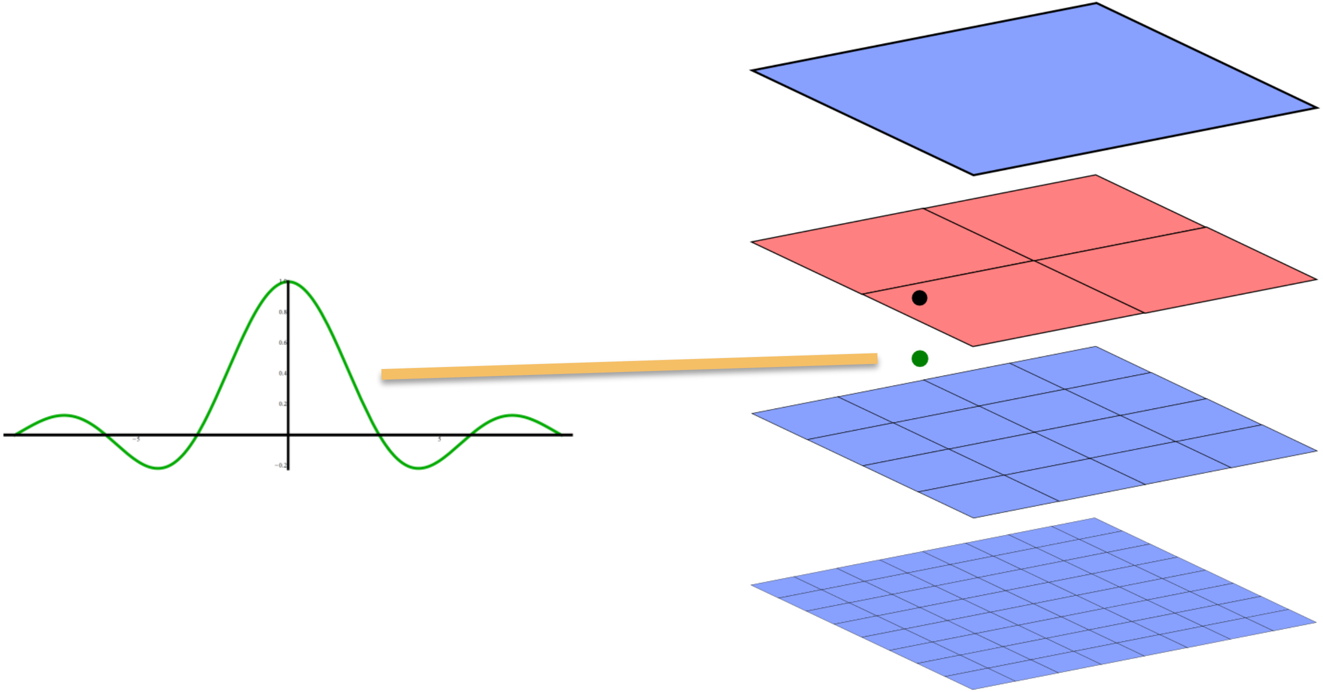


Mipmapping





Mipmapping



Mipmapping

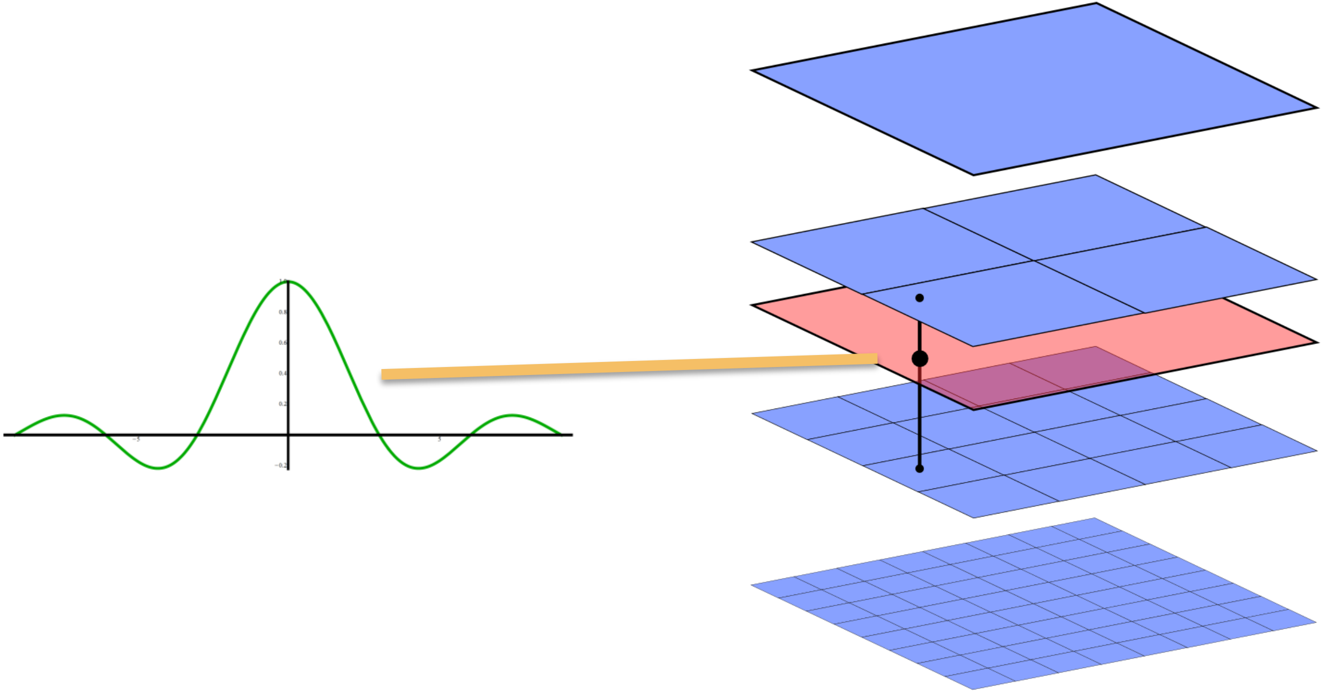


Image Sampling

Input

Exact

Image Sampling

Input

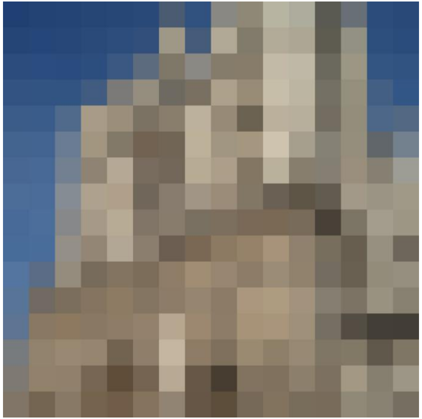
Trilinear

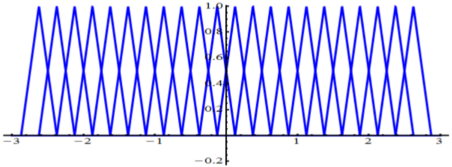
Image Sampling

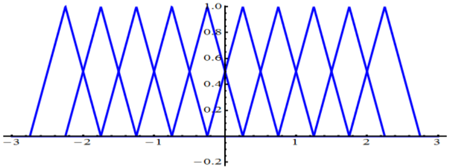
Input

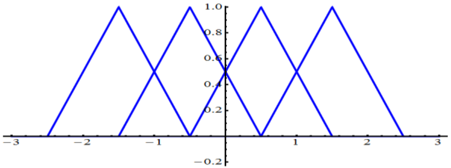
Our Method

Image Sampling









Filter Approximation

$$v_i = \iint_{\mathbb{R}^2} I(x) h_i(x) \, dx$$

Filter Approximation

$$v_i = \iint_{\mathbb{R}^2} I(x) h_i(x)\, dx$$

$$c_1 v_1 + c_2 v_2$$

Filter Approximation

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$$c_1 v_1 + c_2 v_2$$

$$c_1 \iint_{\mathbb{R}^2} I(x) h_1(x)\, dx + c_2 \iint_{\mathbb{R}^2} I(x) h_2(x)\, dx$$

Filter Approximation

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$$v_i = \iint_{\mathbb{R}^2} I(x) h_i(x) \, dx$$

$$c_1 v_1 + c_2 v_2$$

$$c_1 \iint_{\mathbb{R}^2} I(x) h_1(x) \, dx + c_2 \iint_{\mathbb{R}^2} I(x) h_2(x) \, dx$$

$$\iint_{\mathbb{R}^2} I(x) \big(c_1 h_1(x) + c_2 h_2(x) \big) \, dx$$

Filter Approximation

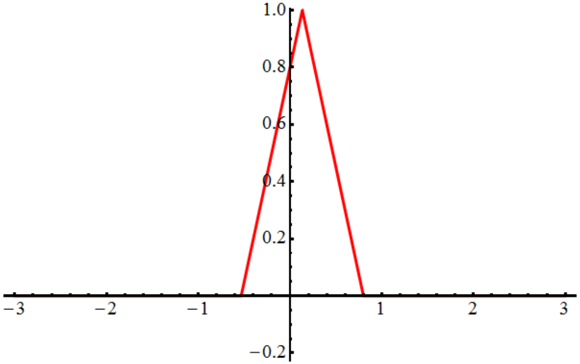
$$v_i = \iint_{\mathbb{R}^2} I(x)\boxed{h_i(x)}\, dx$$

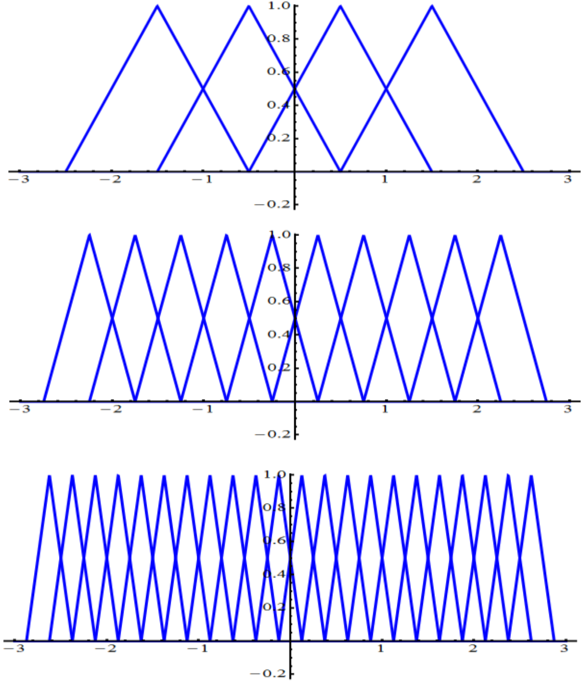
$$c_1 v_1 + c_2 v_2$$

$$c_1 \iint_{\mathbb{R}^2} I(x) h_1(x)\, dx + c_2 \iint_{\mathbb{R}^2} I(x) h_2(x)\, dx$$

$$\iint_{\mathbb{R}^2} I(x)\boxed{\left(c_1 h_1(x) + c_2 h_2(x)\right)}\, dx$$

Filter Approximation





Filter Approximation

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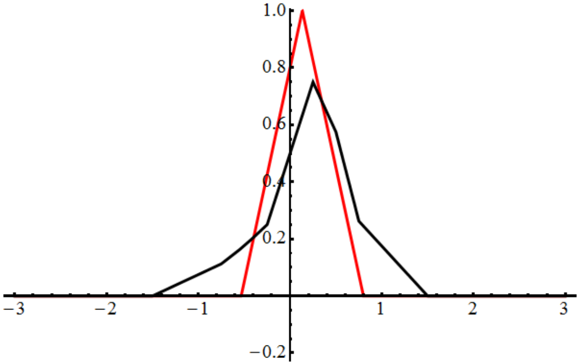
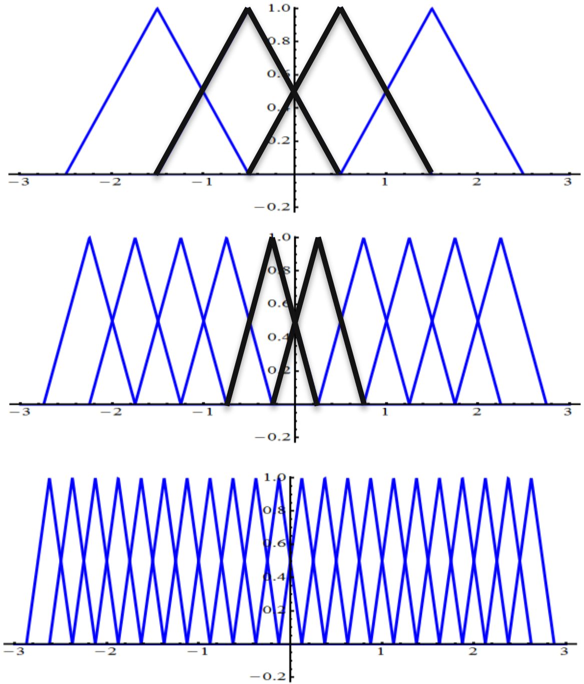


Interpolation of 4 samples



Filter Approximation

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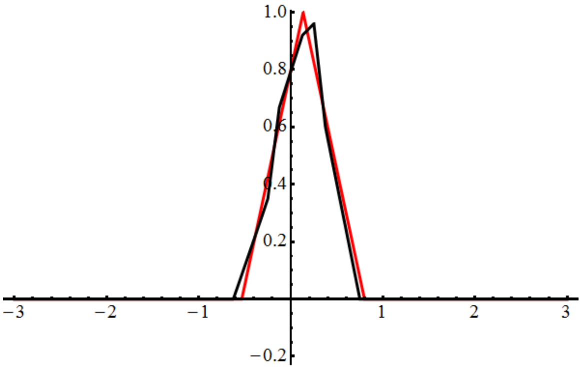
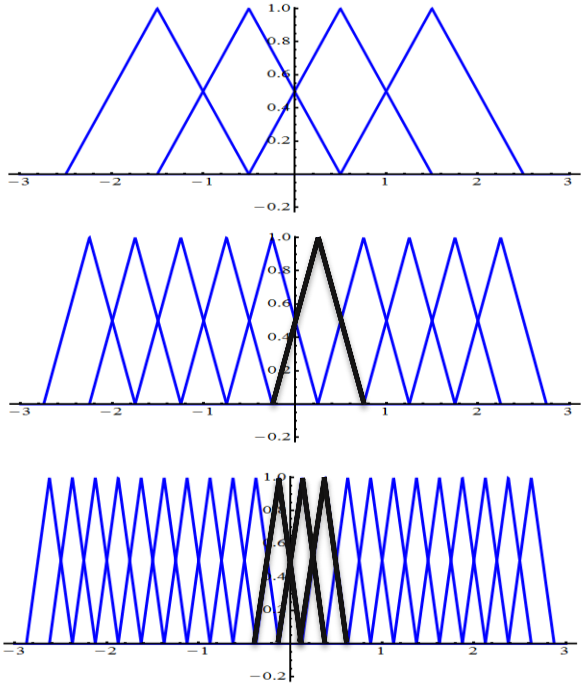


Best fit using 4 samples

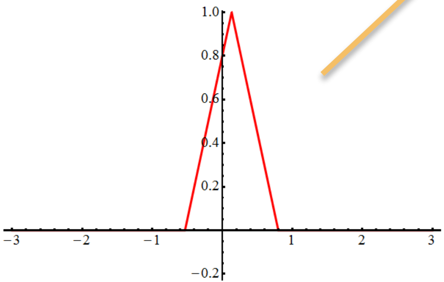


Filter Approximation

$$\operatorname*{argmin}_{c,e \subset E} \iint_{\mathbb{R}^2} \left(h_{\hat{s},\hat{t}}(x) - \sum_{i=1}^{n} h_{e_i}(x) c_i \right)^2 dx$$

Filter Approximation

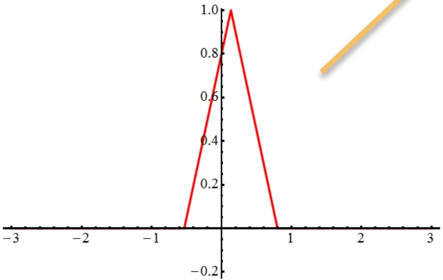
$$\underset{c,e \subset E}{\operatorname{argmin}} \iint_{\mathbb{R}^2} \left(h_{\hat{s},\hat{t}}(x) - \sum_{i=1}^{n} h_{e_i}(x) c_i \right)^2 dx$$

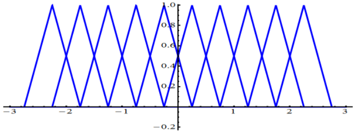


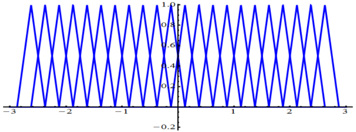
Filter Approximation

SIGGRAPH2013

$$\underset{c,e\subset E}{\operatorname{argmin}} \iint_{\mathbb{R}^2} \left(h_{\hat{s},\hat{t}}(x) - \sum_{i=1}^{n} h_{e_i}(x)c_i\right)^2 dx$$

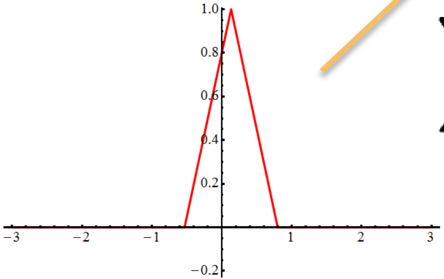




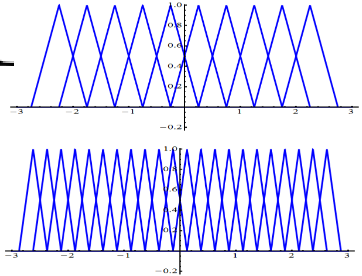


Filter Approximation

$$\underset{c,e\subset E}{\operatorname{argmin}} \iint_{\mathbb{R}^2} \left(h_{\hat{s},\hat{t}}(x) - \sum_{i=1}^{n} h_{e_i}(x)c_i\right)^2 dx$$

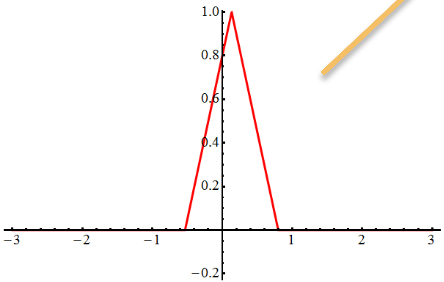


$$\sum c_i = 1$$

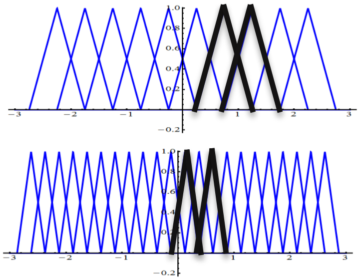


Filter Approximation

$$\underset{c,e\subset E}{\operatorname{argmin}} \iint_{\mathbb{R}^2} \left(h_{\hat{s},\hat{t}}(x) - \sum_{i=1}^{n} h_{e_i}(x)c_i\right)^2 dx$$

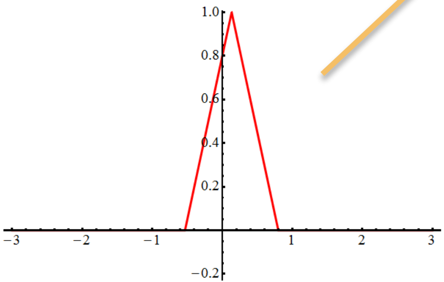


$$|e| = n$$

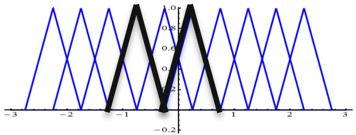


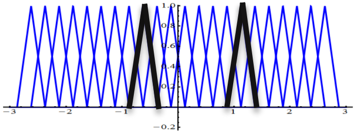
Filter Approximation

$$\underset{c, e \subset E}{\operatorname{argmin}} \iint_{\mathbb{R}^2} \left(h_{\hat{s},\hat{t}}(x) - \sum_{i=1}^{n} h_{e_i}(x) c_i \right)^2 dx$$



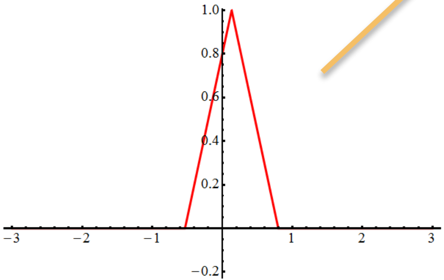
$$|e| = n$$



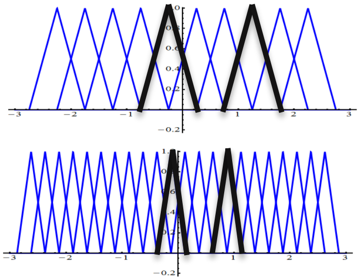


Filter Approximation

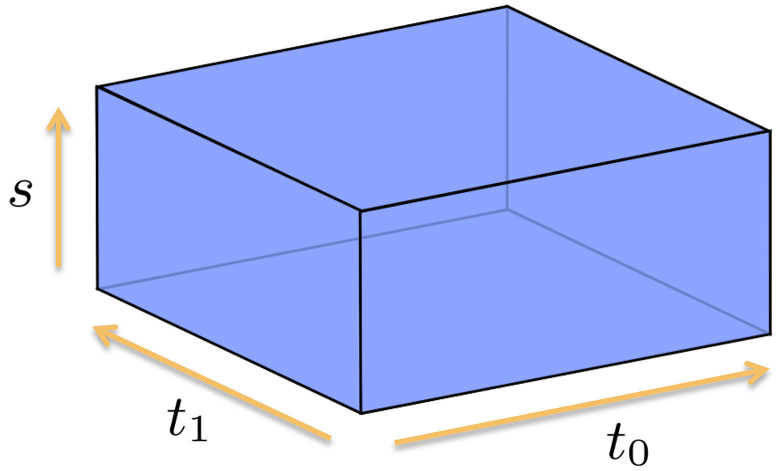
$$\underset{c,e\subset E}{\operatorname{argmin}} \iint_{\mathbb{R}^2} \left(h_{\hat{s},\hat{t}}(x) - \sum_{i=1}^{n} h_{e_i}(x)\, c_i\right)^2 dx$$



$$|e| = n$$



Filter Approximation



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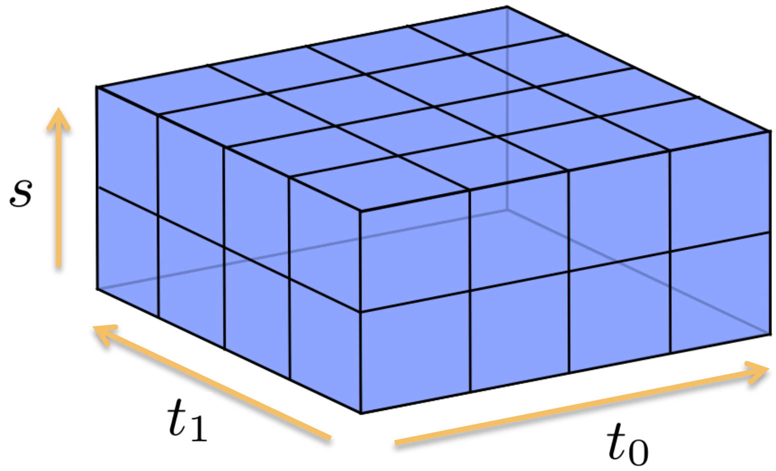
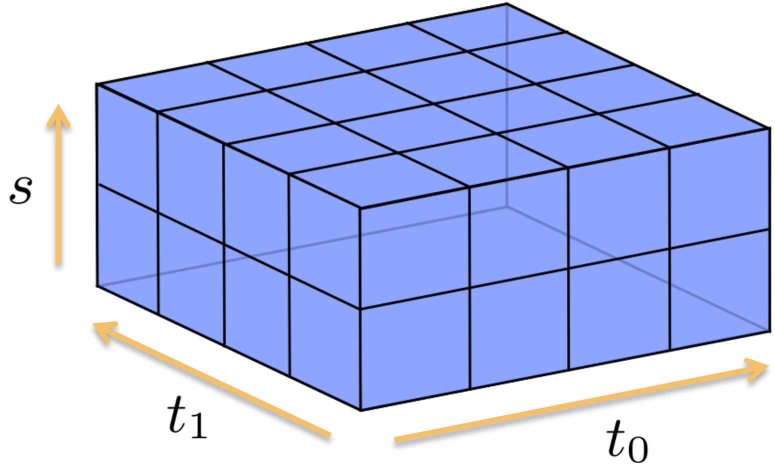


Filter Approximation



$$c_i(s,t) = \sum_j p_j(s,t) c_{ij}$$

Filter Approximation

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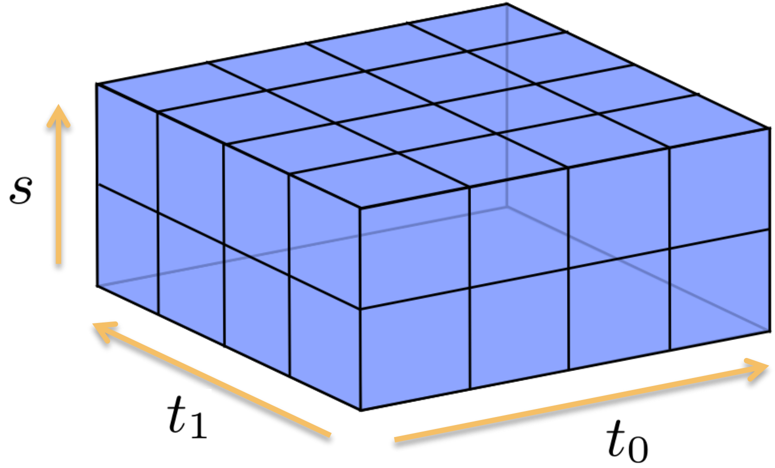
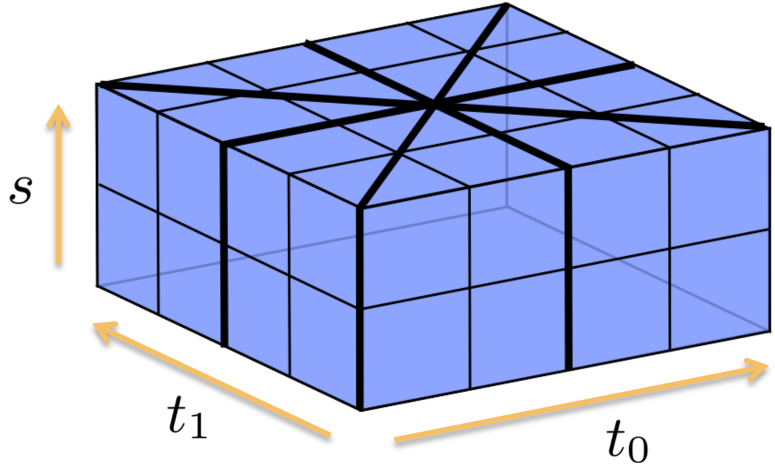


$$c_i(s,t) = \sum_j p_j(s,t)c_{ij}$$

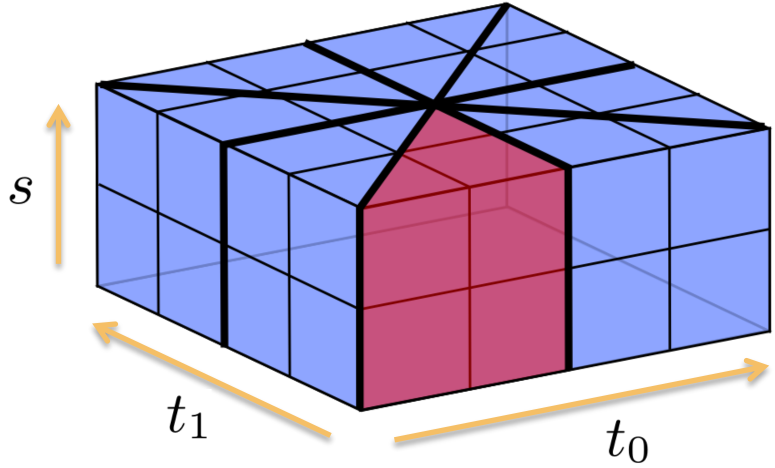
$$p(s,t) = (1, t_0, t_1, s)$$

Filter Approximation



$$c_i(s,t) = \sum_j p_j(s,t) c_{ij}$$
$$p(s,t) = (1, t_0, t_1, s)$$

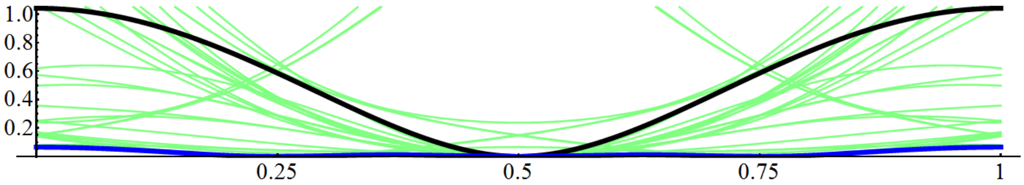
Filter Approximation



$$c_i(s,t) = \sum_j p_j(s,t) c_{ij}$$

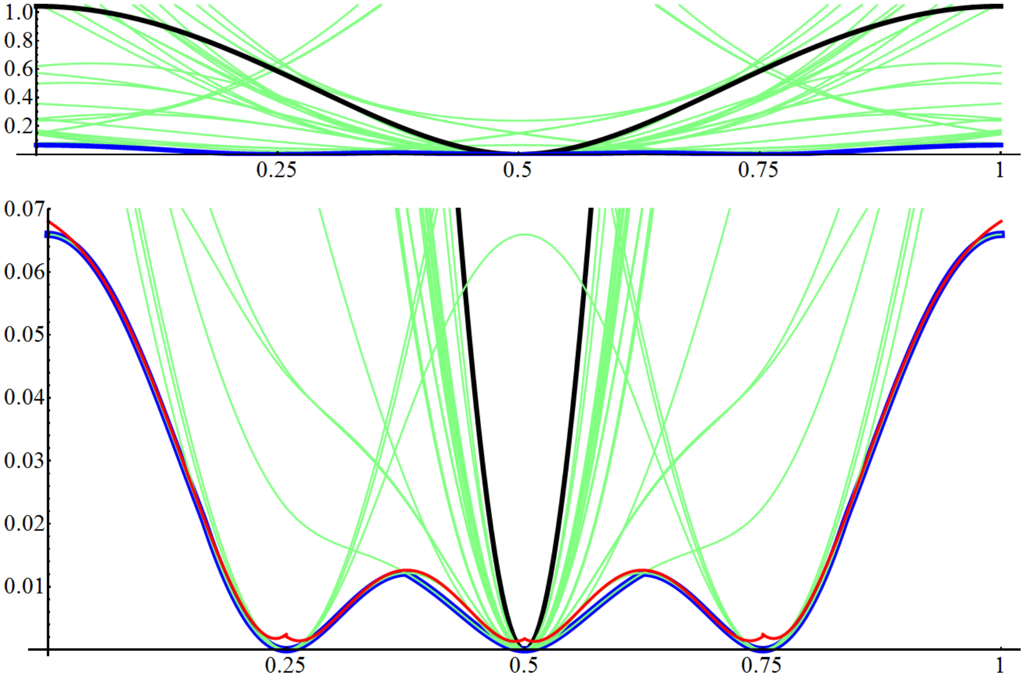
$$p(s,t) = (1, t_0, t_1, s)$$

Fitting Error

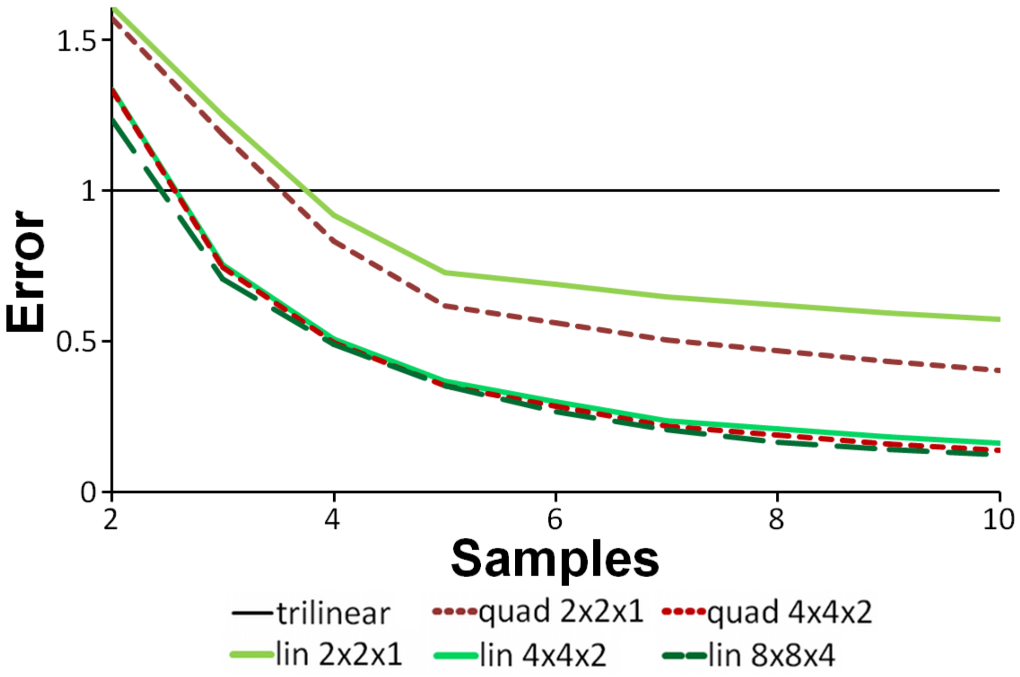


Fitting Error

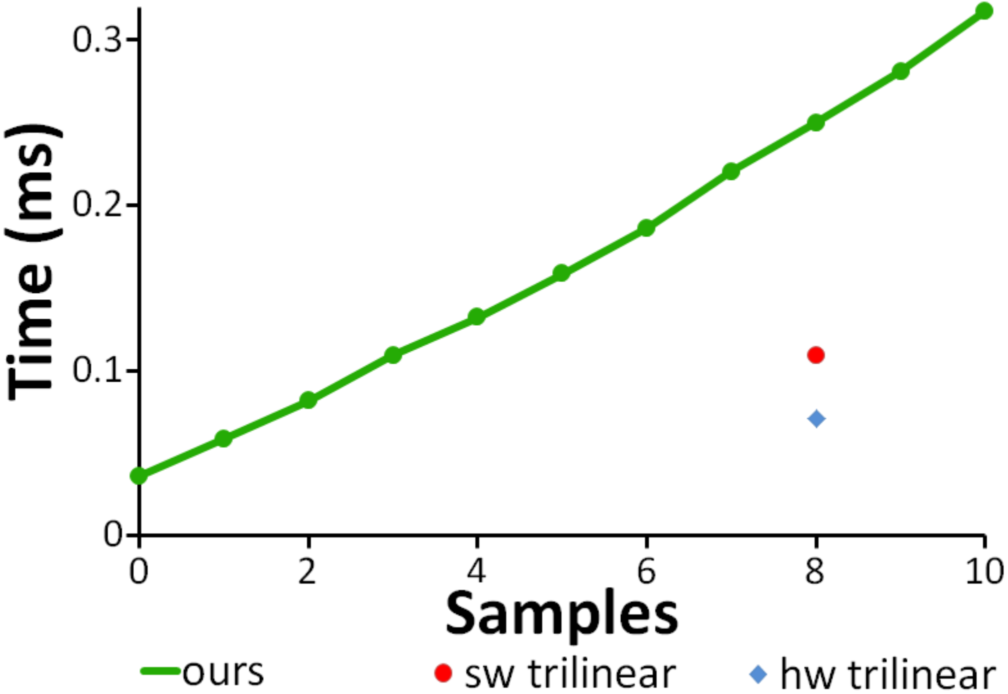
SIGGRAPH2013



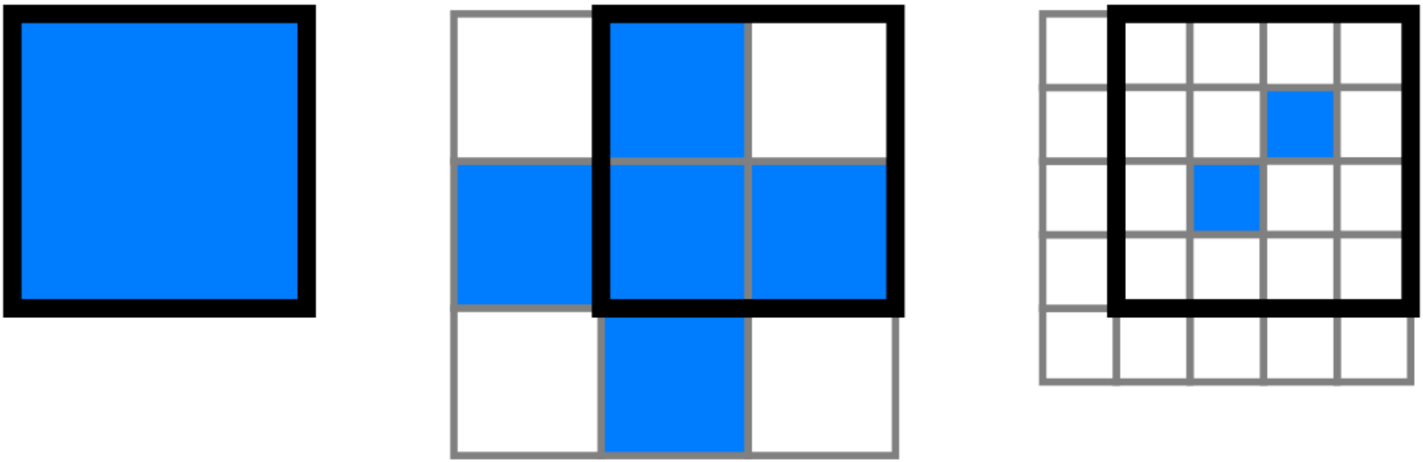
Fitting Error



Speed


Time (ms)
0.3
0.2
0.1
0
0
2
4
6
8
10
Samples
ours
sw trilinear
hw trilinear

Sampling Patterns



Lánczos 2 Approximation

Exact

Trilinear

Lánczos 2 Approximation

SIGGRAPH2013

Exact

8 Samples

Lánczos 2 Approximation

Exact

4 Samples

Scalable Bandwidth

Exact

Trilinear

8 Samples

7 Samples

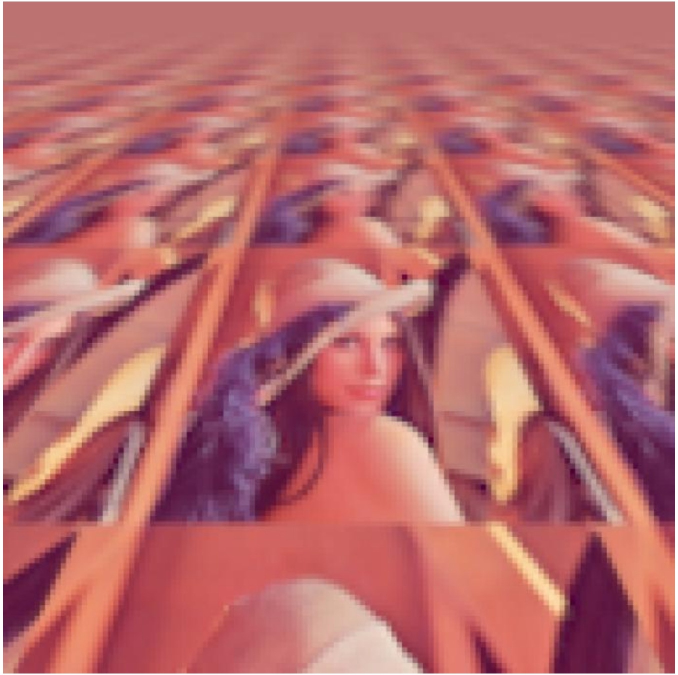
6 Samples

5 Samples

4 Samples

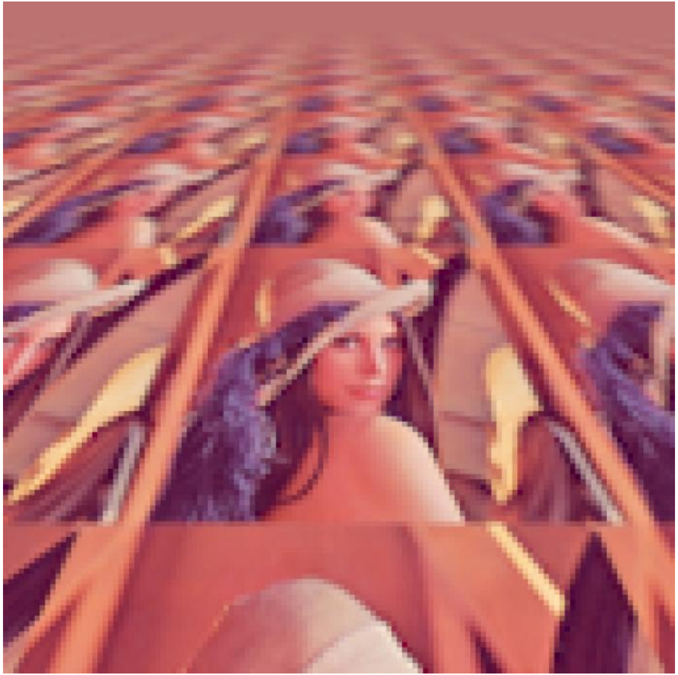
3 Samples

Isotropic Lánczos 2 Approximation



Trilinear

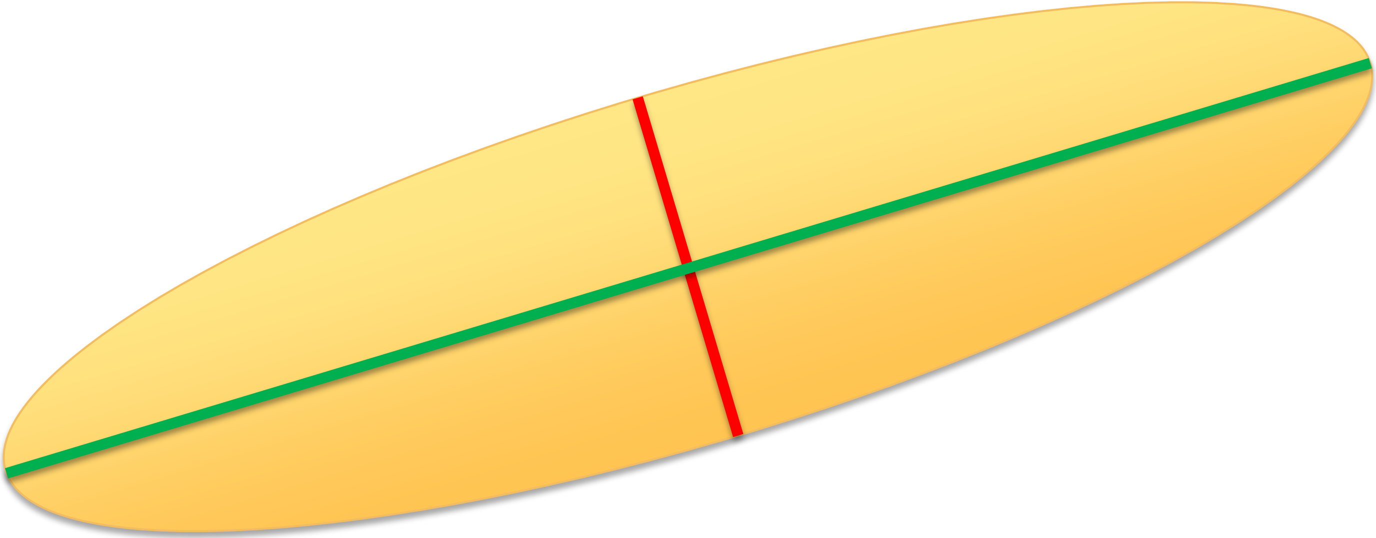
Isotropic Lánczos 2 Approximation



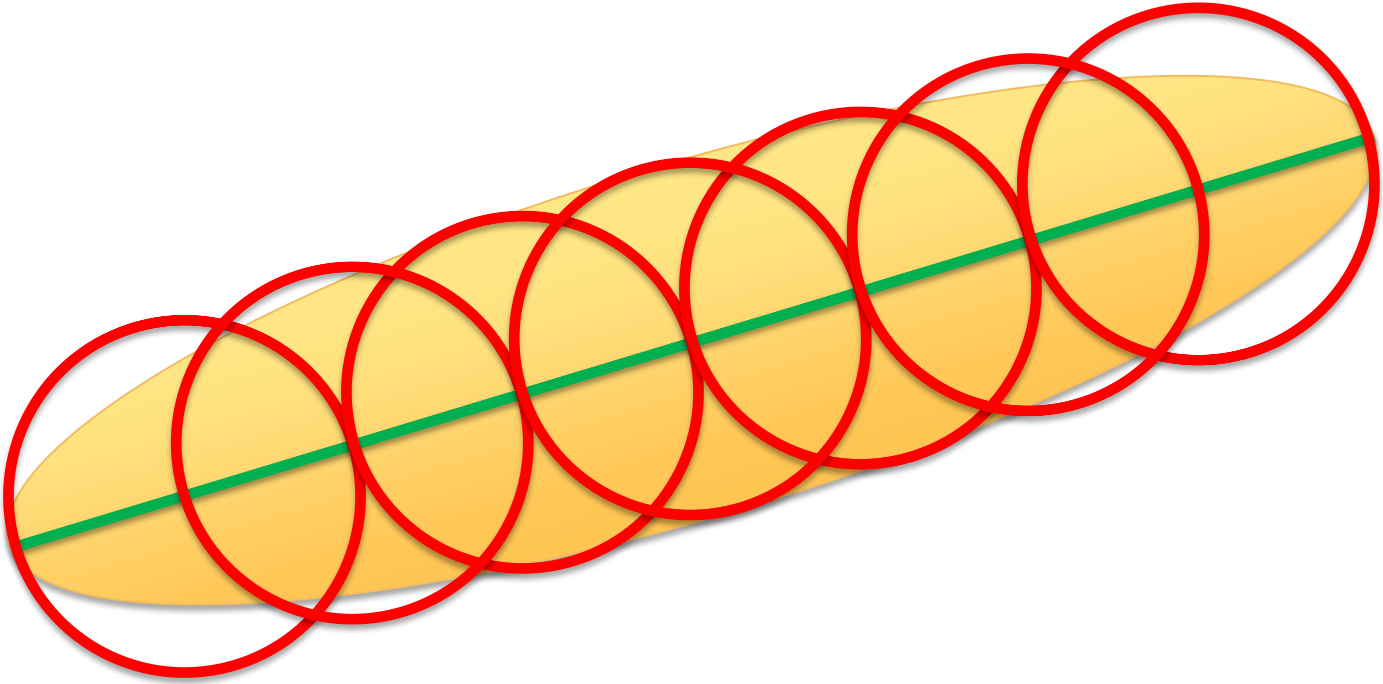
8 Samples

Anisotropic Filtering

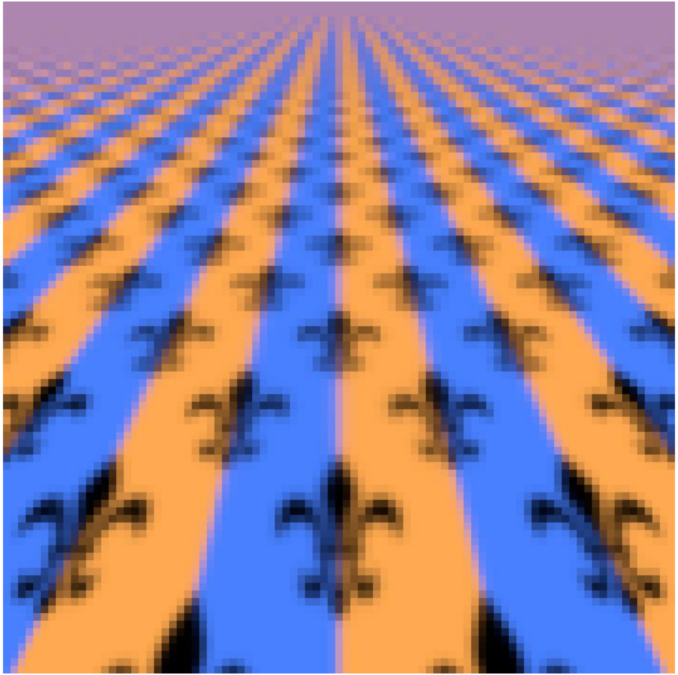
Anisotropic Filtering



Anisotropic Filtering

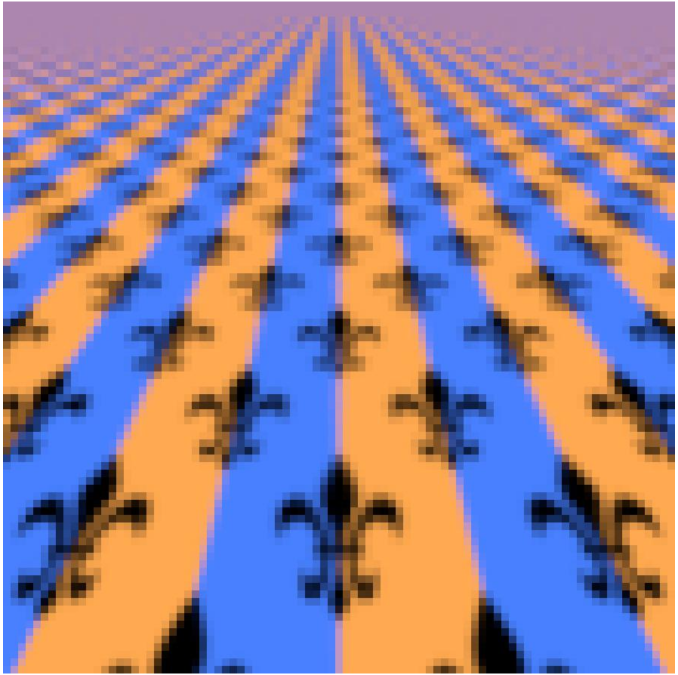


Anisotropic Gaussian Approximation



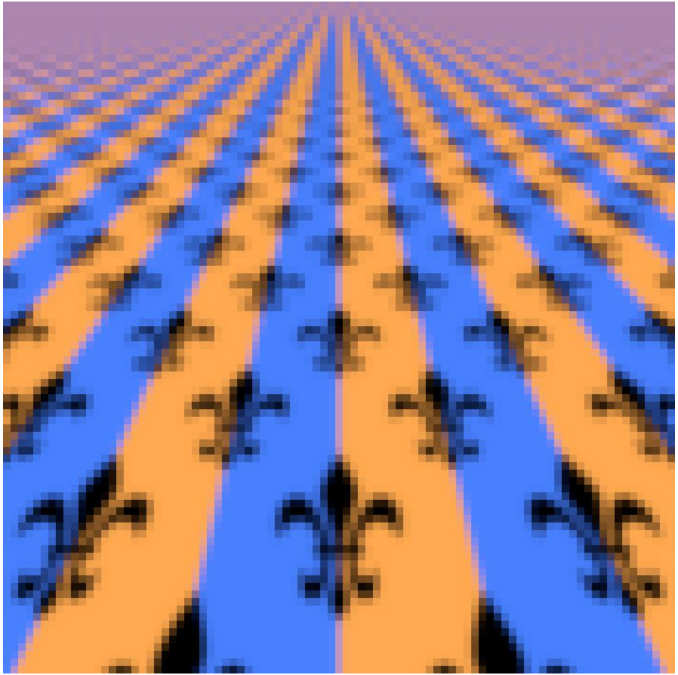
Feline

Anisotropic Gaussian Approximation



8 Samples with Feline

Anisotropic Gaussian Approximation



Exact

Conclusions

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- Higher quality using less bandwidth
  - Scattered reads cost performance
- Approximate filters with few samples
  - Cost is only in preprocessing
- Small lookup tables
  - Easily fits in local memory
- GPU implementation
  - http://josiahmanson.com/research/cardinality_constrained/