Distribution Fields

A Unifying Representation for Low-Level Vision Problems

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Basin of attraction studies

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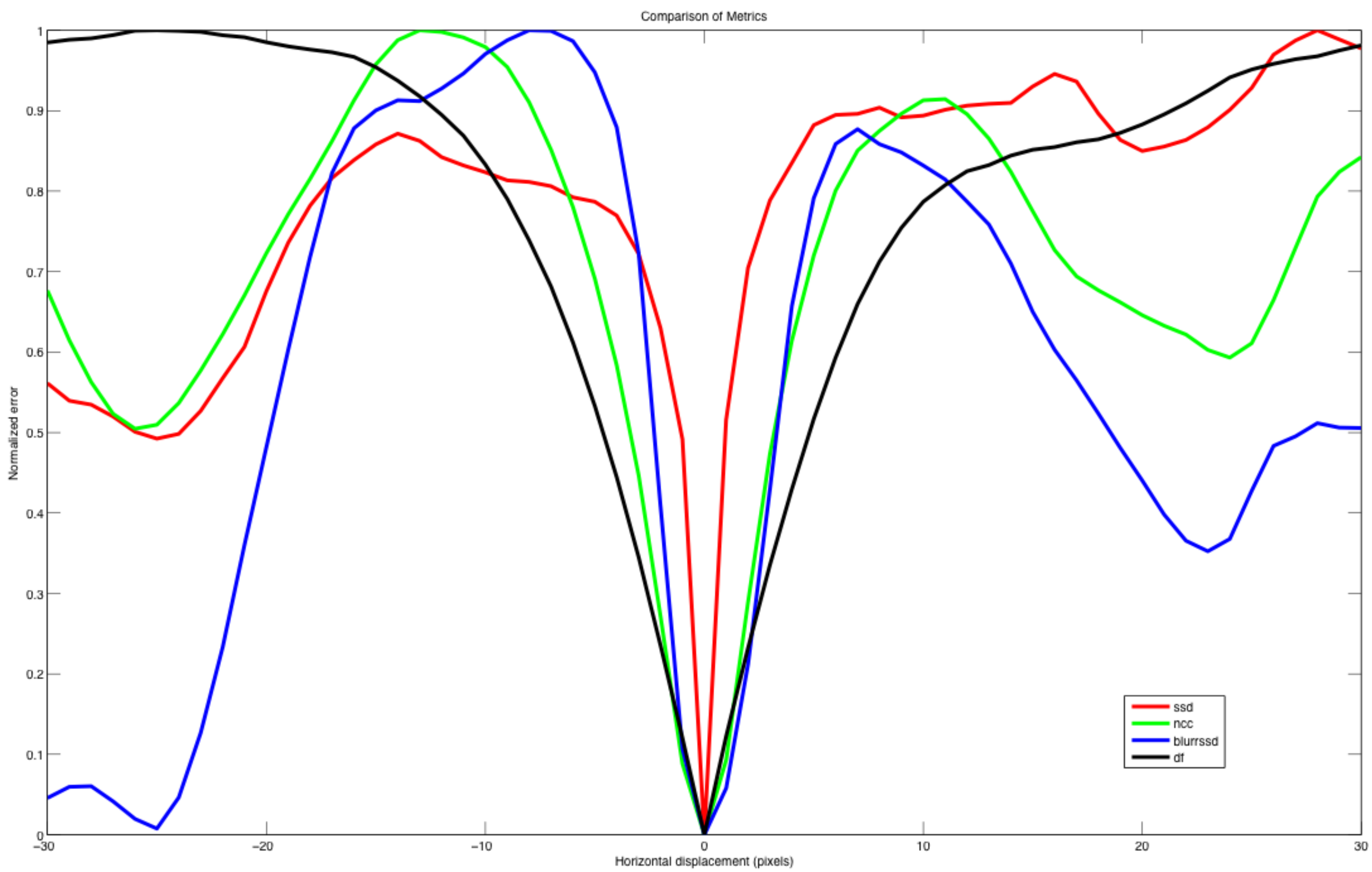
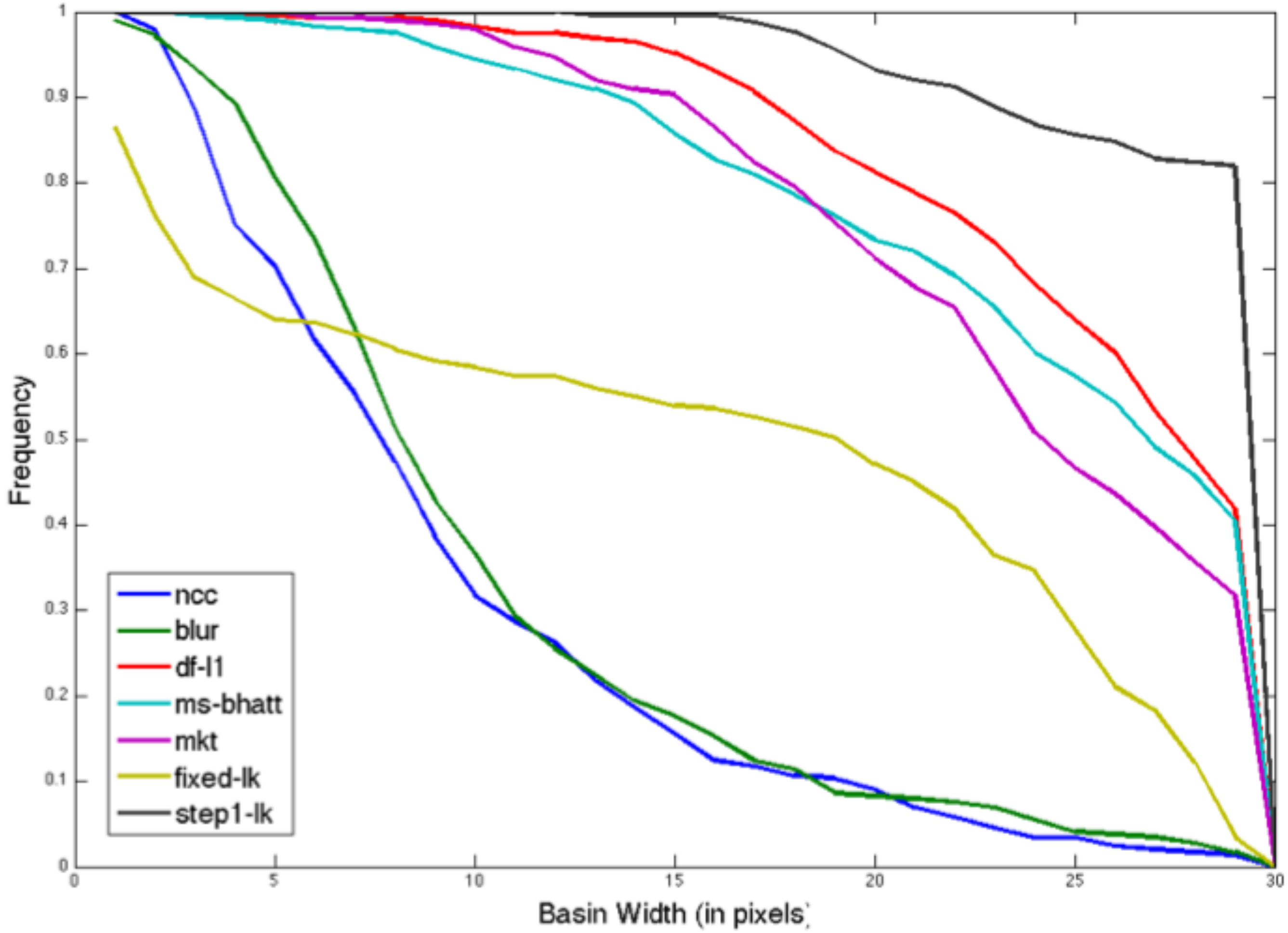
Basin of attraction studies



Basin of attraction results



Question

- How can we get the benefits of congealing without lots of images, and without a massive computational burden?

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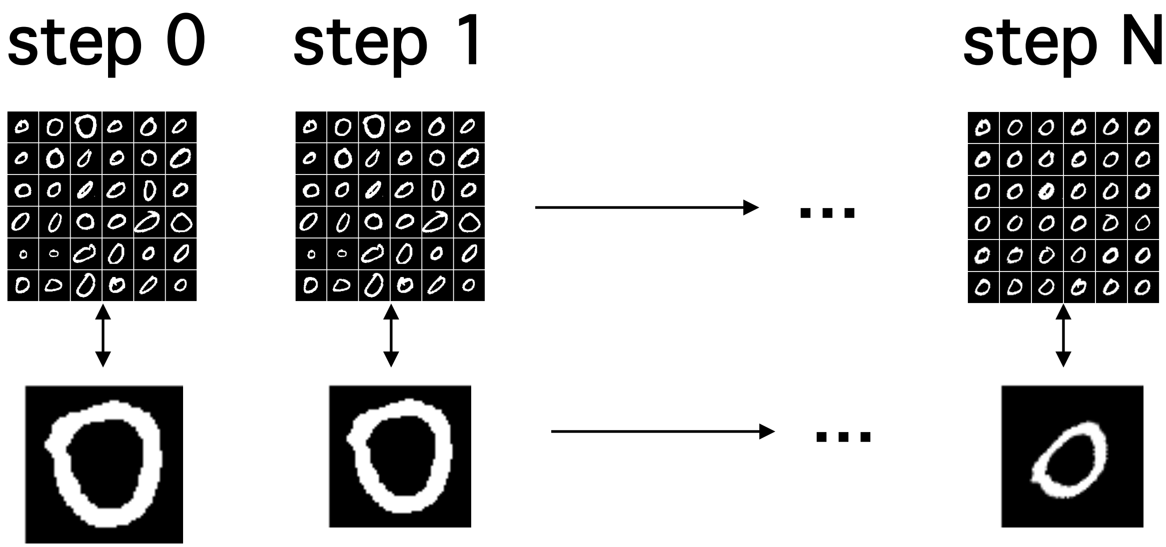
How do we line up a new image? *Funneling…*

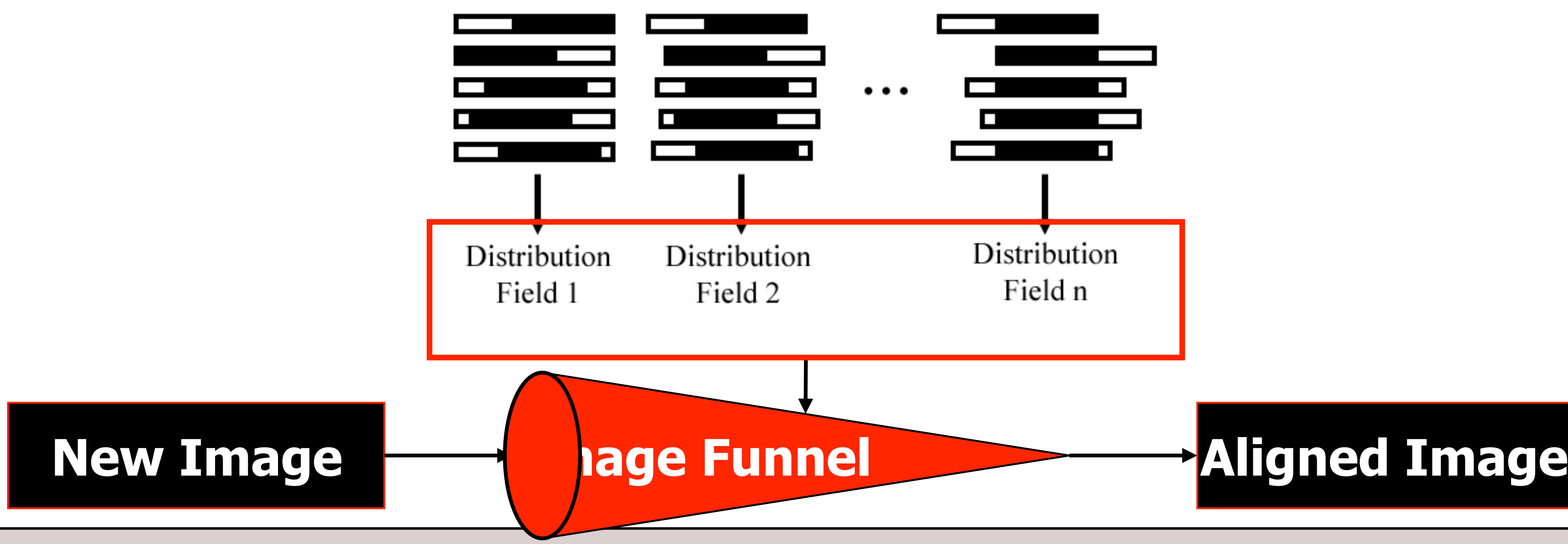
Sequence of successively "sharper" models



Take one gradient step with respect to each model.

How to align a new image after congealing?

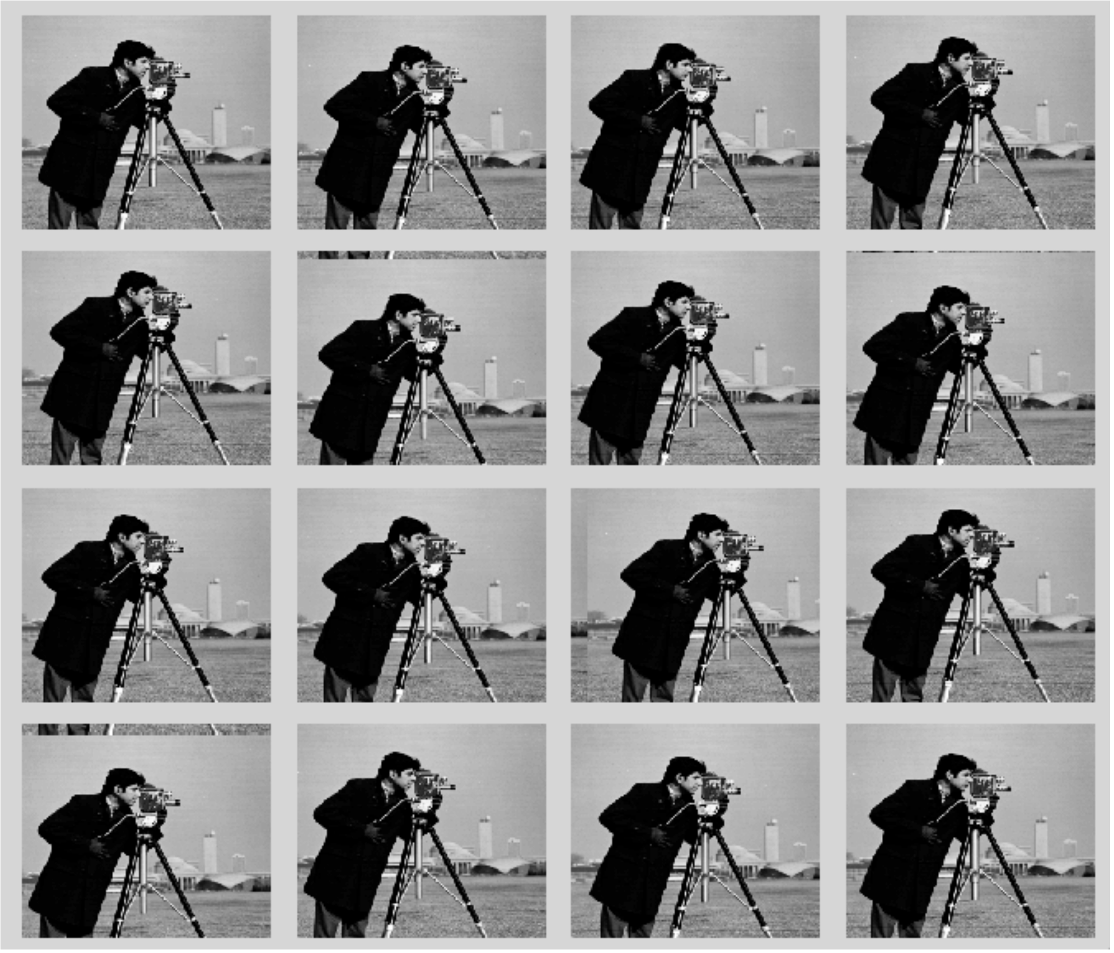
- More efficient to save sequence of distribution fields from congealing
  - High entropy to low entropy sequence → "Image Funnel"
- Funneling: increase likelihood of new image at each iteration according to corresponding distribution field



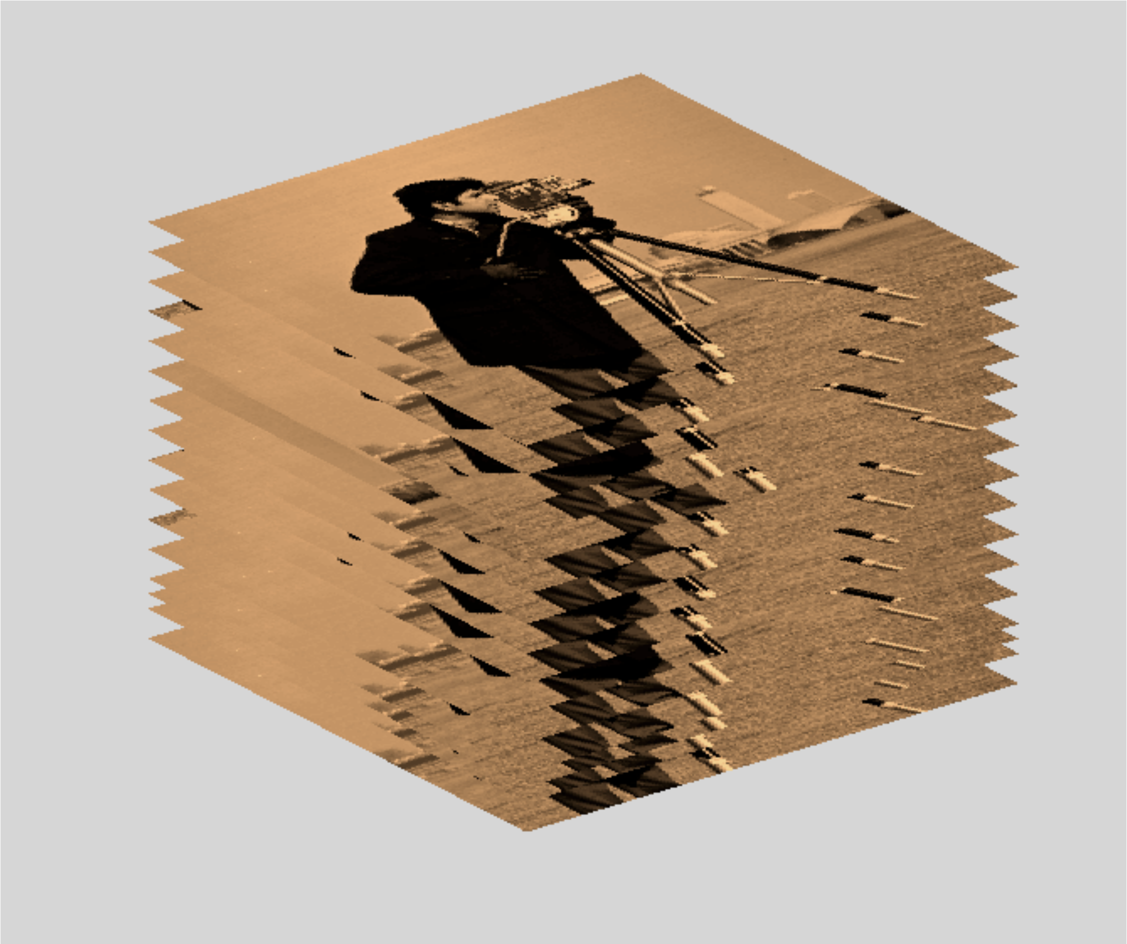
Aligning two images using the funneling concept

- Given image I and image J
- Generate many perturbed versions of image I, including the original image.
- Generate image funnel for set of I images.

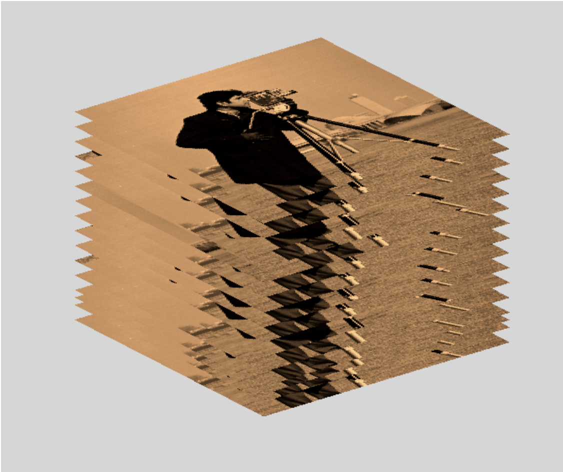
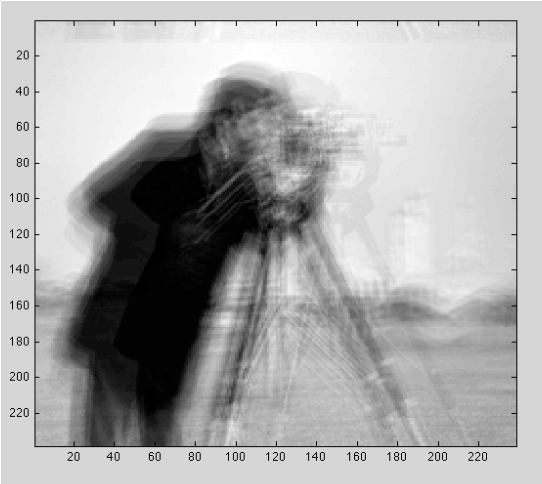
Perturbed versions of an image



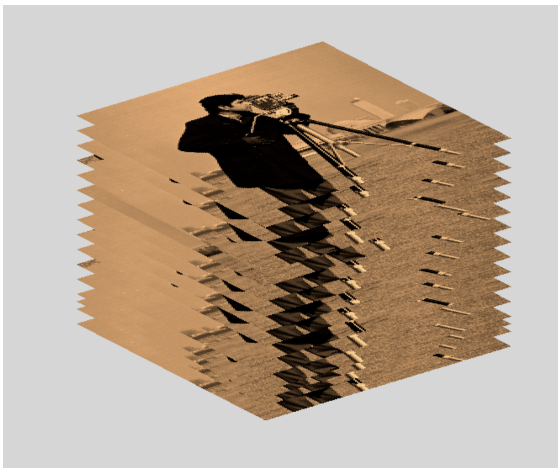
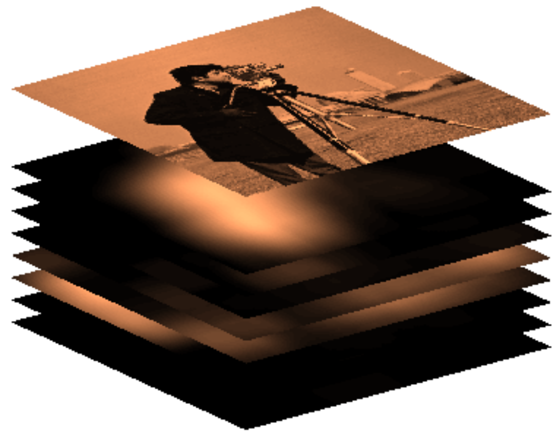
As an image stack.



Summing the perturbed stack.

Sum() = 

Distribution of perturbed stack.

Dist.() = 

Distribution fields

- Is there a simpler way to generate the idea of the distributions in a perturbed stack than to randomly make the images and then compute the distributions?
- Yes, distribution fields.

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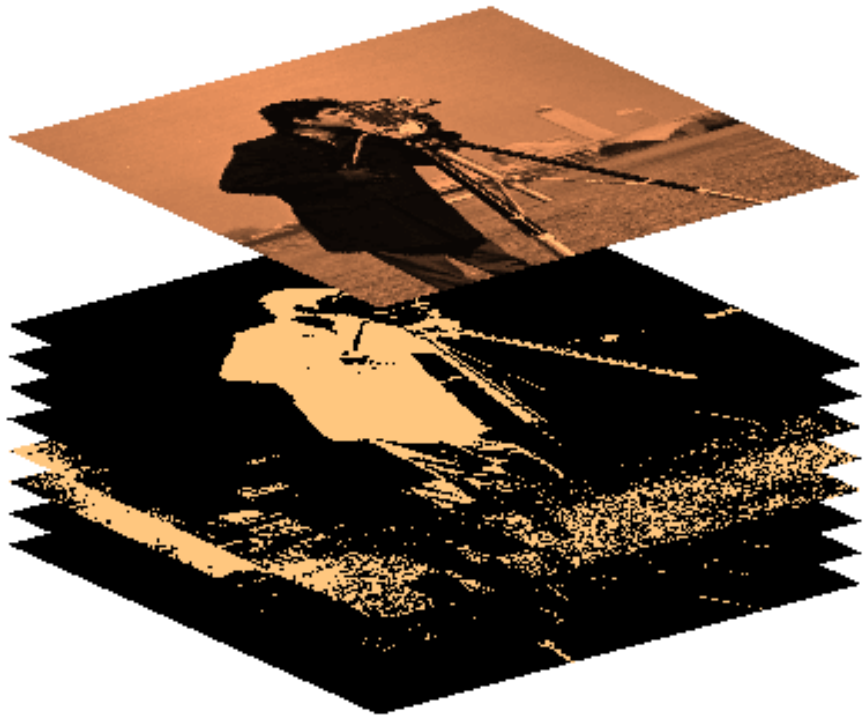
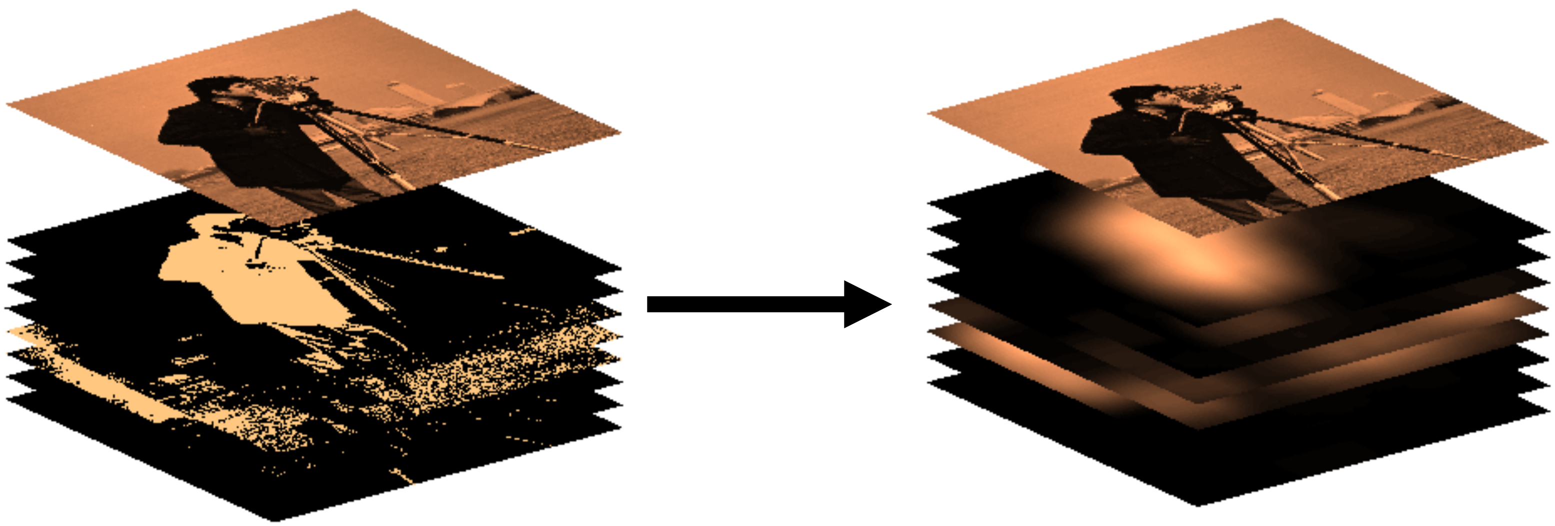
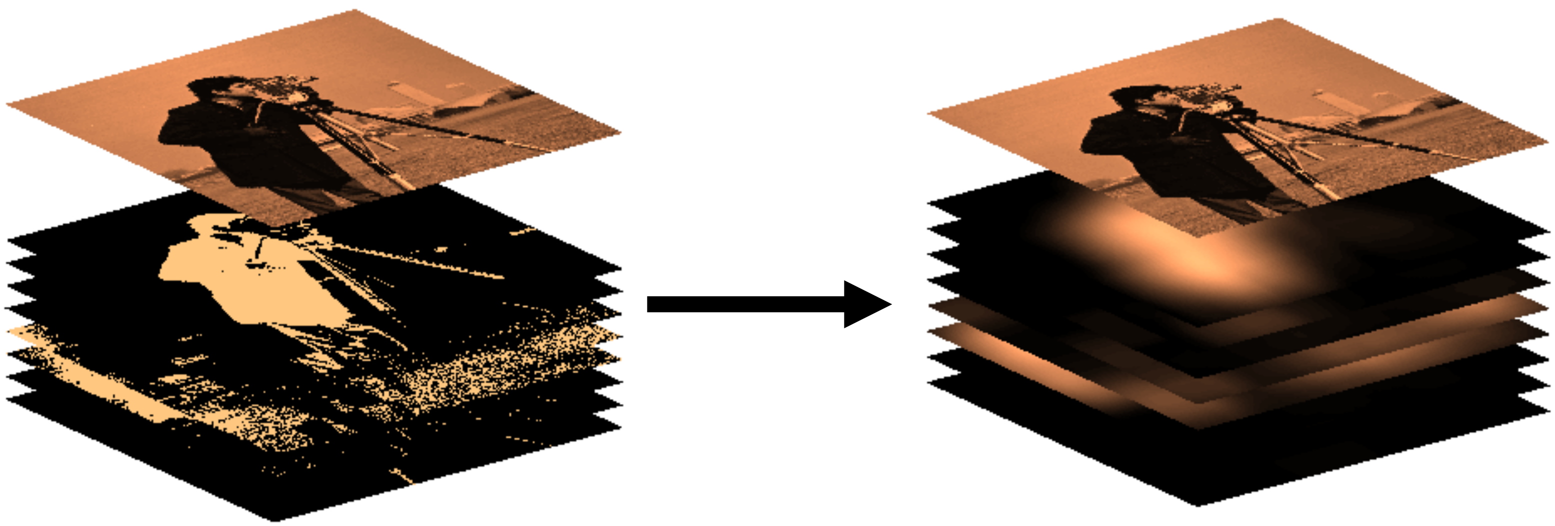
Exploding an image



Spatial Blur: 3d convolution with 2d Gaussian



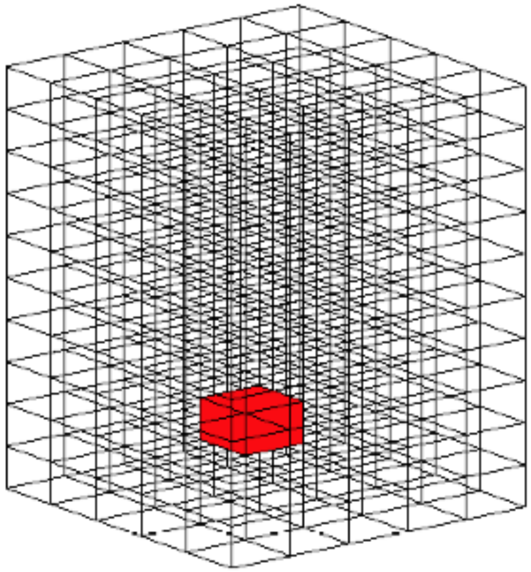
Spatial Blur: 3d convolution with 2d Gaussian



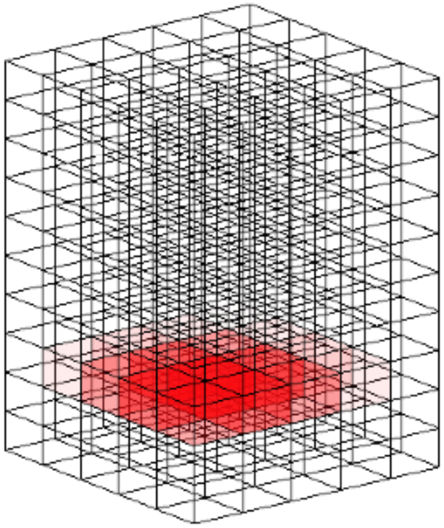
KEY PROPERTY: doesn't destroy information through averaging

Feature space blur

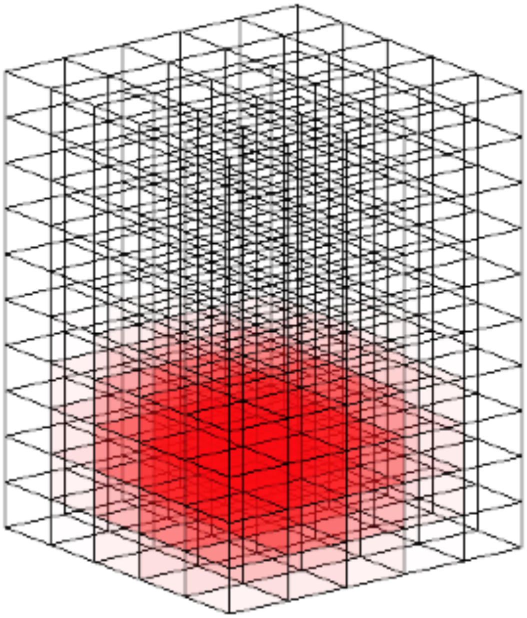
Delta function at one pixel



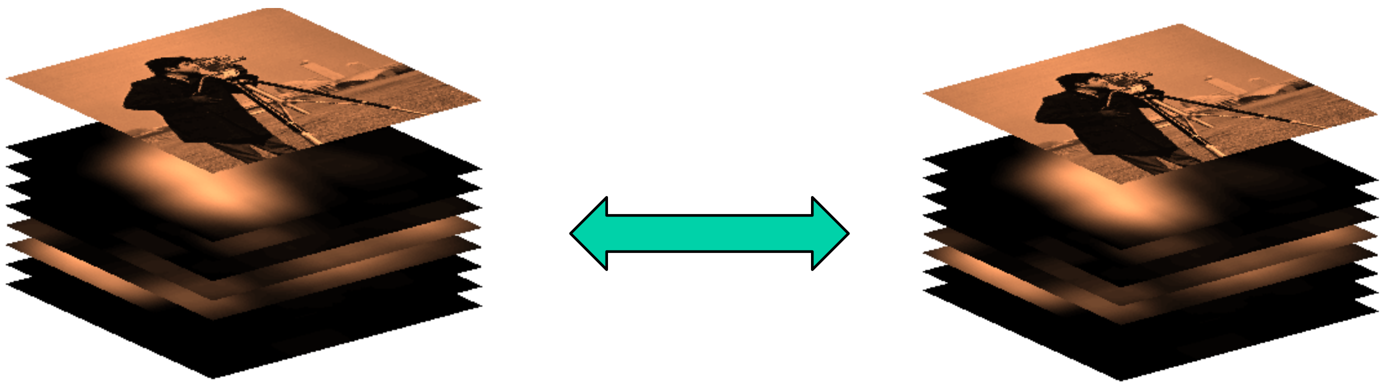
Spatial blur



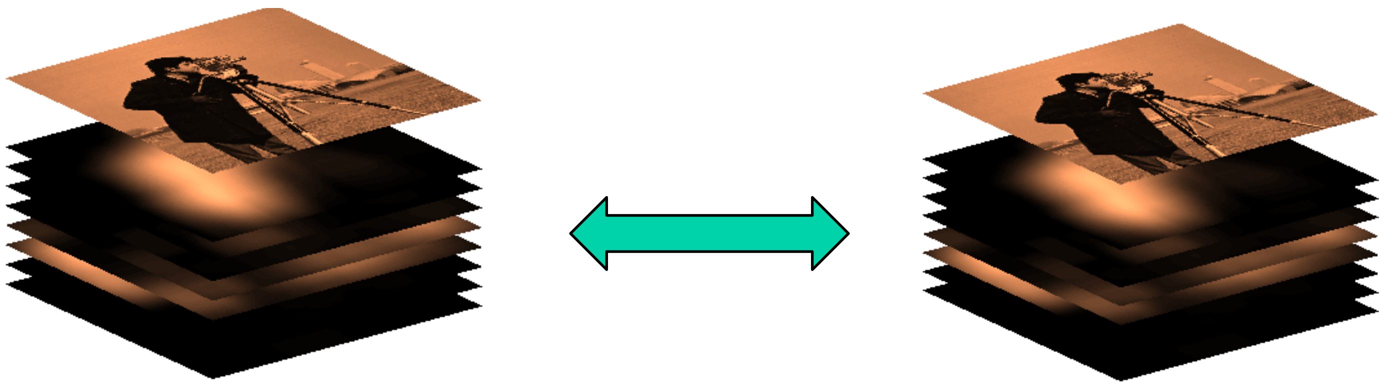
Spatial and feature-space blur



How to compare?



How to compare?



- L1 distance?
- L2 distance?
- KL divergence?

The likelihood match

- Recall image I and patch J.
- Make a distribution field out of I and evaluate the likelihood of J under the field.

Image I

Patch J

The likelihood match

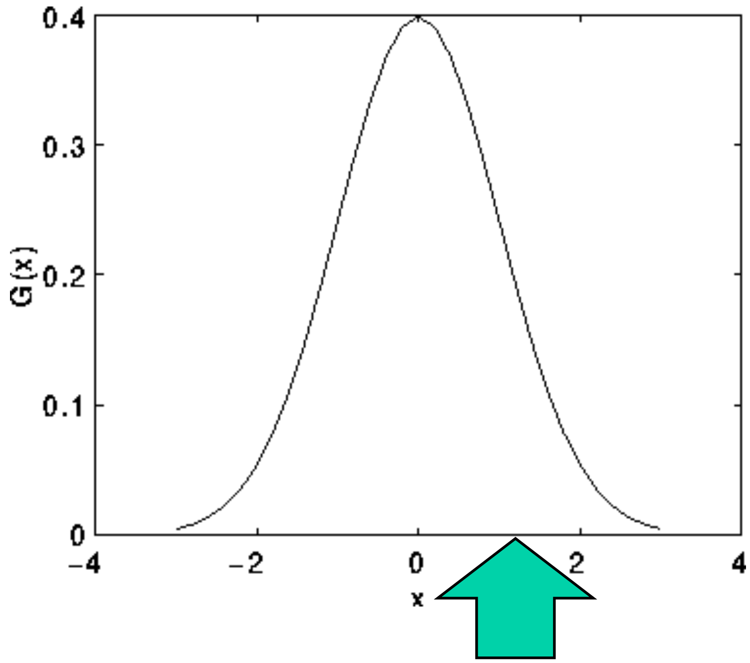
Given distribution field $D = D(I; \sigma)$ and image J.

$$Prob(J) \quad = \quad \prod_{i=1}^{N} p_{x,y}(J_{x,y})$$

Sharpening match

$$\max_{\sigma} Prob(J;\sigma) \quad = \quad \prod_{i=1}^{N} p^{\sigma}_{x,y}(J_{x,y})$$

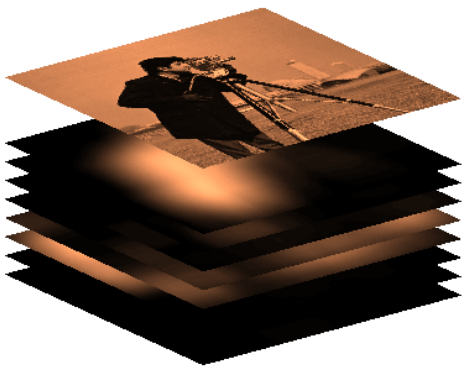
Understanding the sharpening match



What standard deviation maximizes the likelihood of a given point under a zero-mean Gaussian?

Intuition behind sharpening match

- Increase standard deviation until it matches "average distance" to matching points.



Properties of the sharpening match

- A patch has probability of 1.0 under its own distribution field.
- Probability of an image patch degrades gracefully as it is translated away from best position.
- Optimum "sigma" value gives a very intuitive notion of the quality of the image match.

Tracking results

- State of the art results on tracking with standard sequences
  - Very simple code
  - Trivial motion model
  - Simple memory model

It’s not perfect…

Closely Related work

- Mixture of Gaussian backgrounding (Stauffer...)
- Shape contexts (Belongie and Malik)
- Congealing (me)
- Bilateral filter
- SIFT (Lowe), HOG (Dalal and Triggs)
- Geometric Blur (Berg)
- Rectified flow techniques (Efros, Mori)
- Mean-shift tracking
- Kernel tracking
- and many others...

- Lots more applications
  - Backgrounding
  - Image matching
  - Pixel unmixing
  - Superresolution

Motivations

- A distance between images:
  - Many metrics "broken" by slight misalignments.
    - Measure of distance or similarity should degrade gracefully with transformation.
  - "Invariant metrics" throw away a lot of information.
    - Integrating over regions
      - “max pooling”
      - Averaging over regions
    - Lose fine-grained spatial info:
      - Face recognition

Spatial Blur: Compare to regular image blur