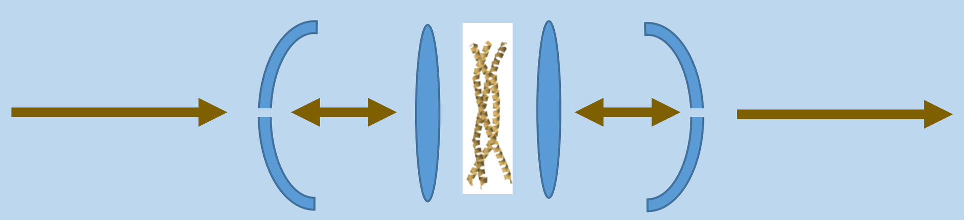
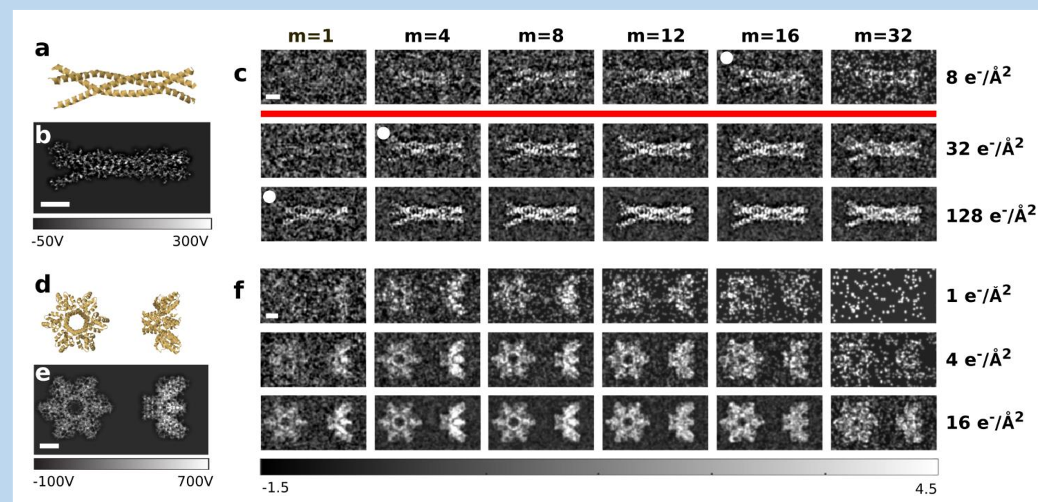
Un-wrapping Multi-Passed Images

Stewart Koppell skoppell@Stanford.edu Stanford University, CS 229

The Application

Multi-pass optical and electron microscopy: less damage at constant signal to noise





The problem

$I \rightarrow MI$

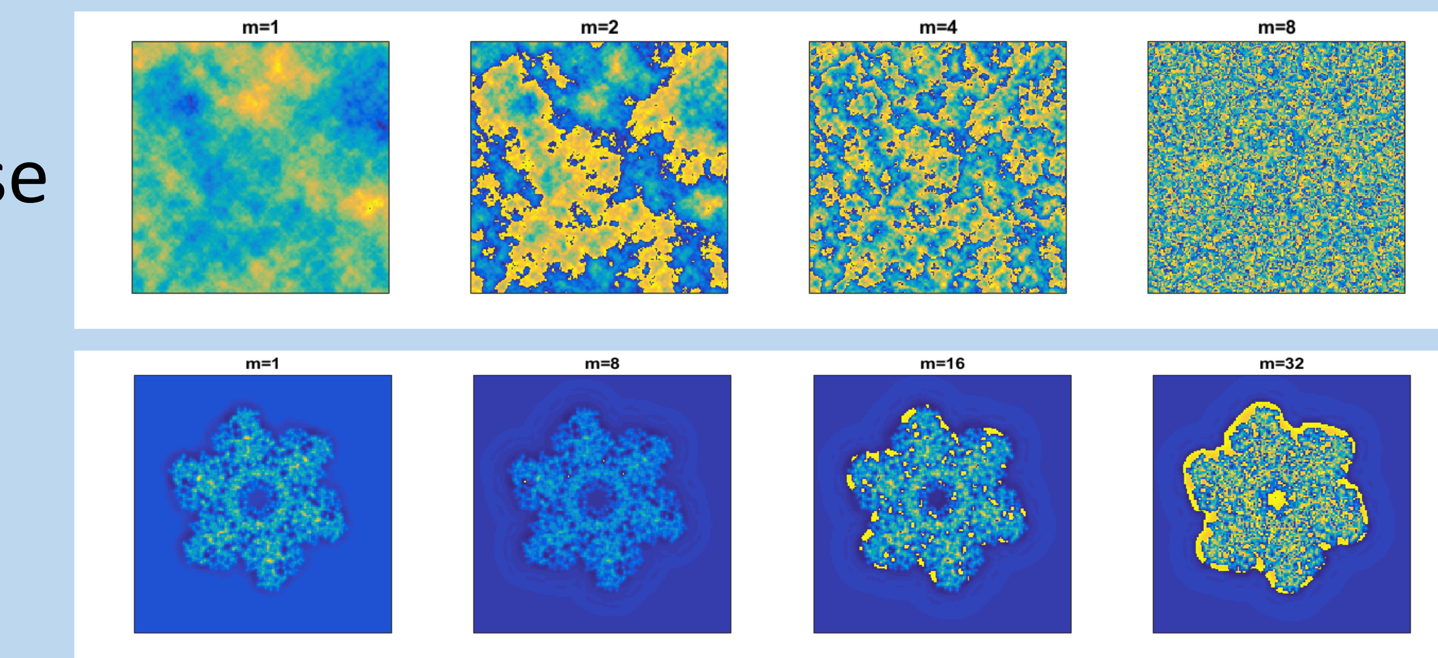
$\hat{I} = mod(MI, 1)$

$MI = \hat{I} + N$

Given only $\hat{I}$, how do we find I?

Perlin noise

HIV-1 Gag (protein)



1st attempt: K-Means

First, with training data:

- $\{x^{(i)}\}$ are nxn pixel blocks from images like I.
- Subtract means, then find the magnitude of the Fourier transform to get $\{X^{(i)}\}$.
- Cluster $\{X^{(i)}\}$ into K groups to obtain a library of representative images $\{Y^{(k)}\}$

Now, with test data

- $\{x^{(i)}\}$ are nxn pixel blocks from images like $\hat{I}$.
- Calculate $\{X^{(i)}\}$.
- For each i, choose k by $\text{argmin}_k \Sigma_{pl}(X_{pl}{}^{(i)} - \text{mod}(MY_{pl}{}^{(k)}))^2$
- Find the phases of $Y^{(k)}$
- $y^{(k)} \approx$ unwrapped $x^{(i)}$

This… didn't work.

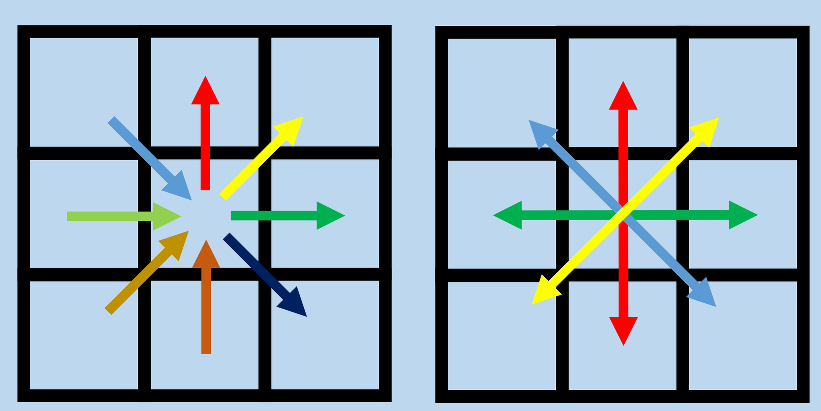
2nd attempt: EM

$x^{(i)}$ is a 3x3 pixel block from $\hat{I}$

$z^{(i)}$ is a 3x3 pixel block from N

$P(z=j) \sim \phi_j$ $P(x|z) \sim P(D)$

$D = [d_{\uparrow}^{[1]}, d_{\nearrow}^{[1]}, \ldots, d_{\updownarrow}^{[2]}, \ldots]$



$d^{[1]}$ $d^{[2]}$

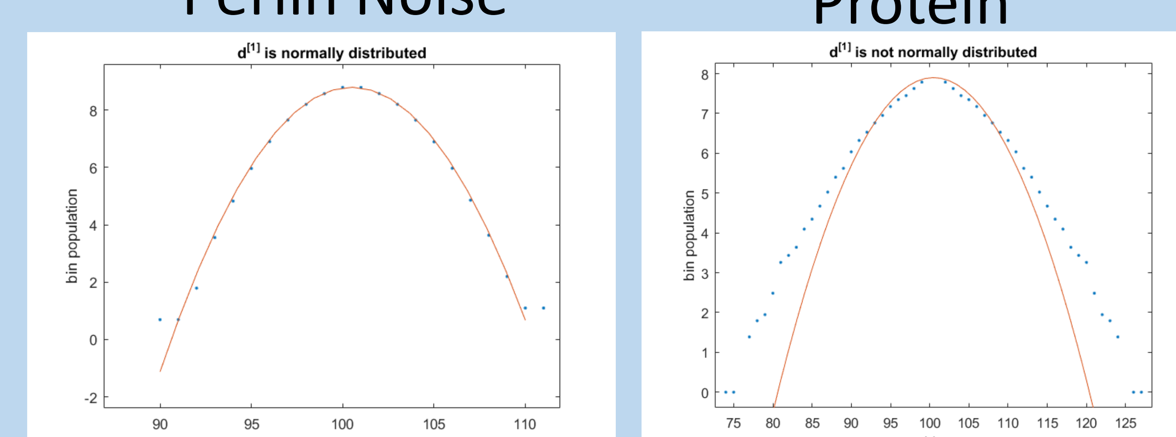
$w^{(i)} = x^{(i)} + z^{(i)}$

$d_{\uparrow}^{[1]} = w^{(i)}_{12} - w^{(i)}_{22}$

$d_{\updownarrow}^{[2]} = w^{(i)}_{12} - 2w^{(i)}_{22} + w^{(i)}_{32}$

$P(D(x^{(i)}, z^{(i)})) \sim N(\mu, \Sigma)$?

Perlin Noise Protein

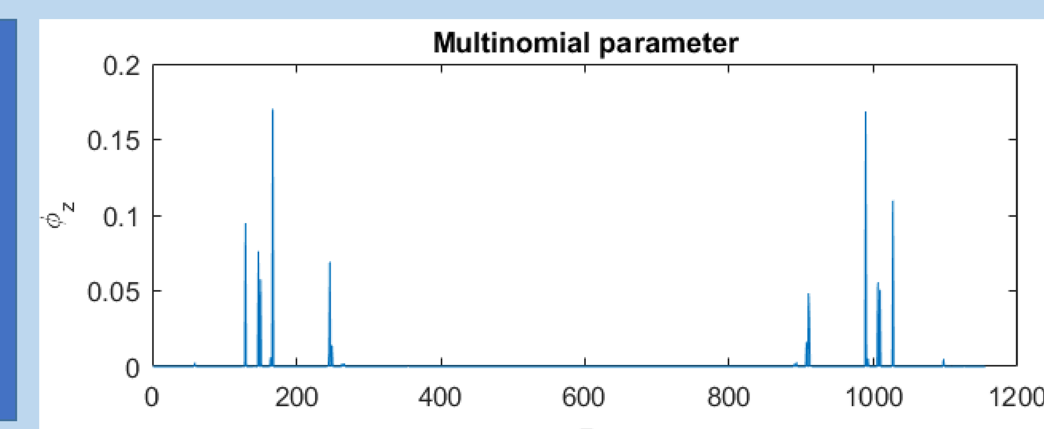


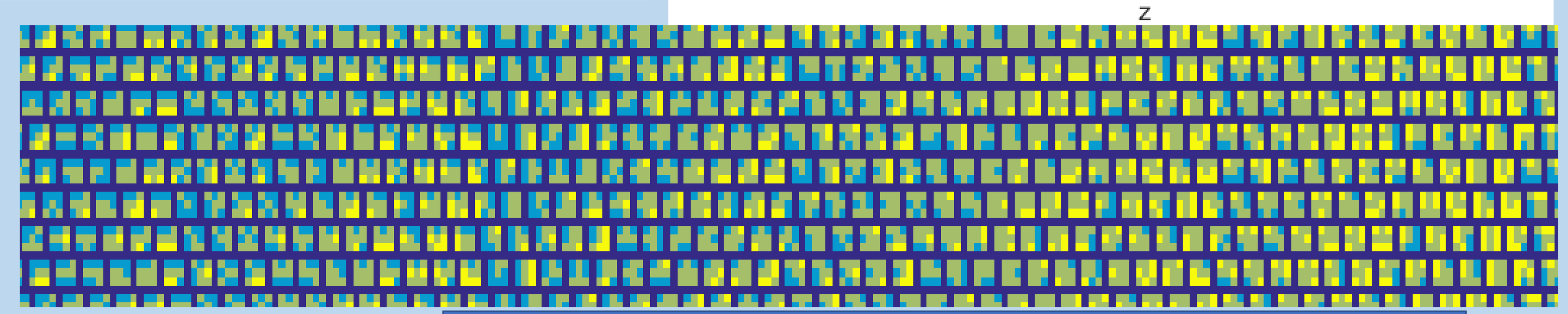
E-Step:

$$Q_i(z^{(i)}) = \frac{p(x^{(i)}, z^{(i)})}{\sum p(x^{(i)}, z)}$$

M-step:

Update μ, Σ, and ϕ





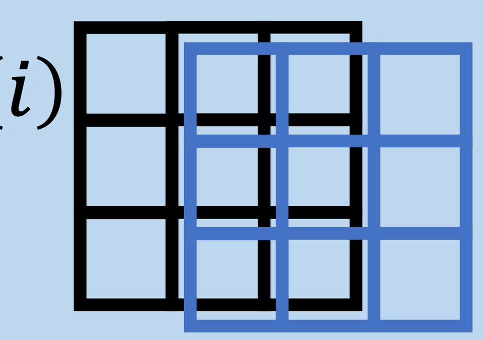
Results

Max pixel accuracy: 67%

Max block accuracy: 46%

Future Work

Stitching Procedure



Current algorithm determines $w^{(i)}$ up to an integer offset. Use overlap pixels to determine relative offsets of all pixel blocks.

Over-lap pixels can also increase confidence in prediction of $z^{(i)}$:

References

Juffmann, T. et. al., ``Multi-Pass Transmission Electron Microscopy", Scientific Reports 7, Article number: 1699 (2017)

Protein Data Bank website: https://www.rcsb.org/