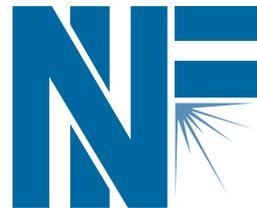


Image Registration for NIF Optics Inspection

**Presentation to
CASIS, Signal and Imaging Sciences Workshop**



Judy Liebman, Laura Kegelmeyer, Marijn Bezuijen

November 18-19, 2004

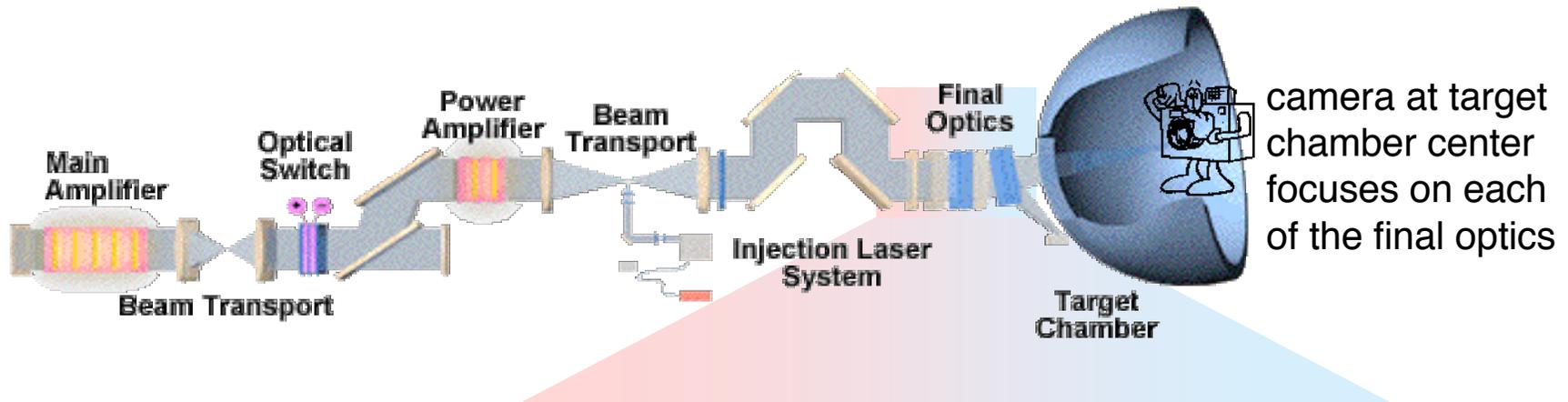
UCRL-PRES-208127

This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract.

Final Optics Inspection Setup



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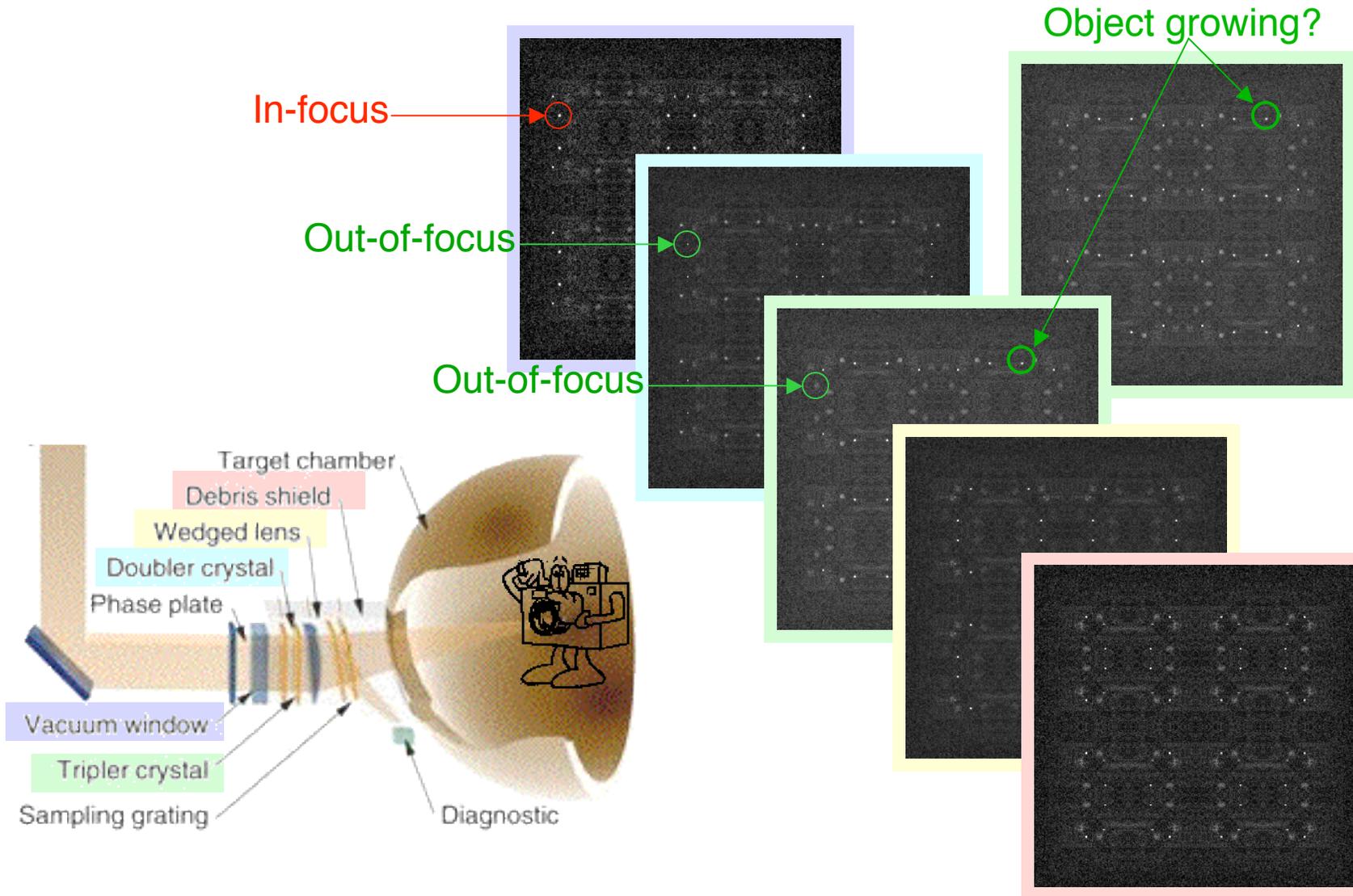
camera at target chamber center focuses on each of the final optics



Current Final Optics Registration



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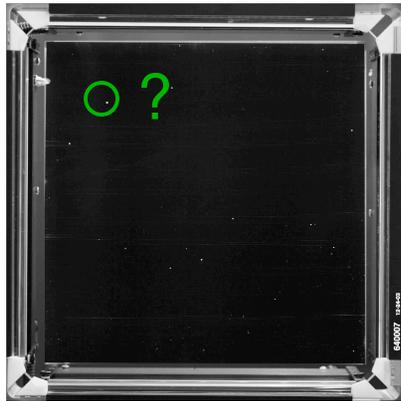


Future Registration Adventures

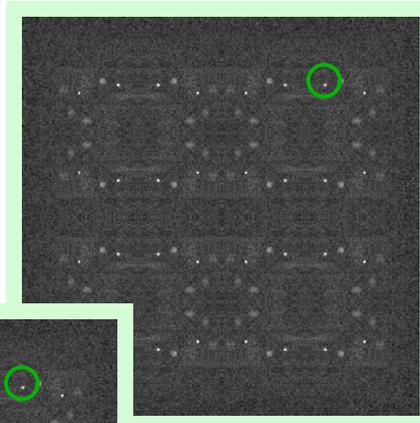


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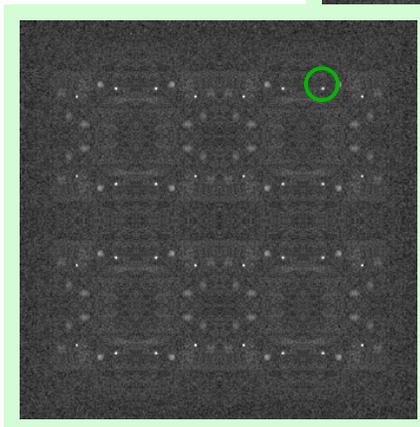
- Optic lifetime reporting – follow optic health through online and offline imaging



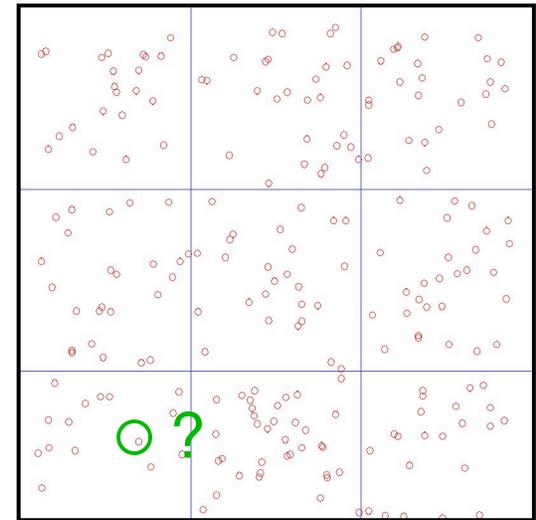
Future offline damage map



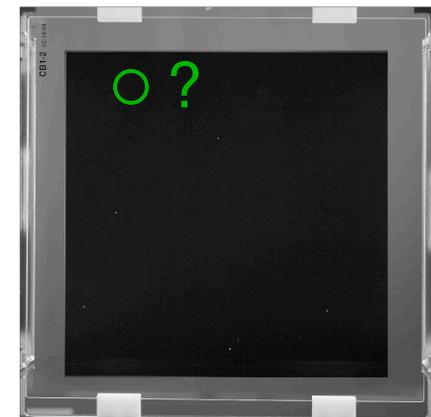
Previous inspection



Current inspection



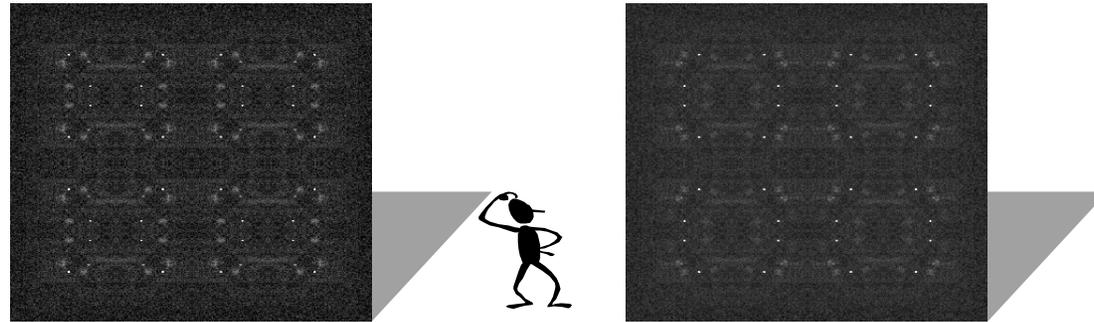
Initial offline inclusion map



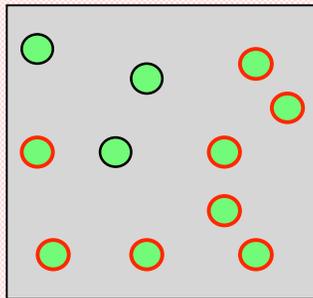
Initial offline damage map

Registration Problem Characteristics

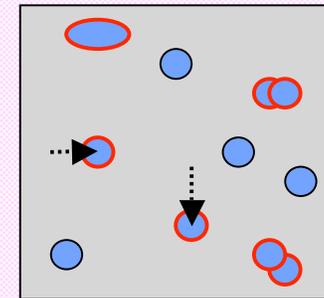
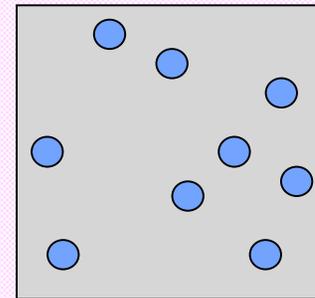
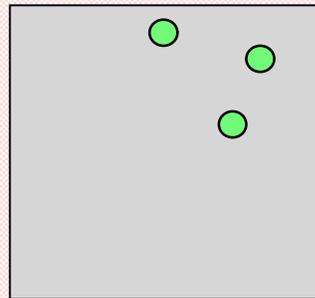
- 35MB images



- Lots of noise!

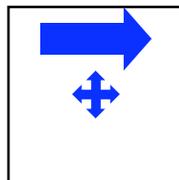


outliers

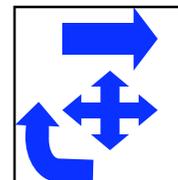


perturbation errors

- Transformation type:



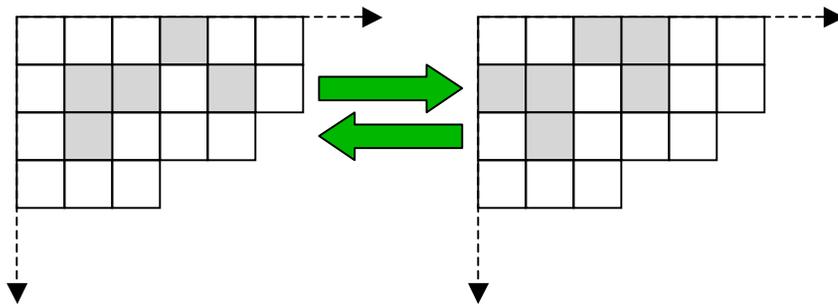
current



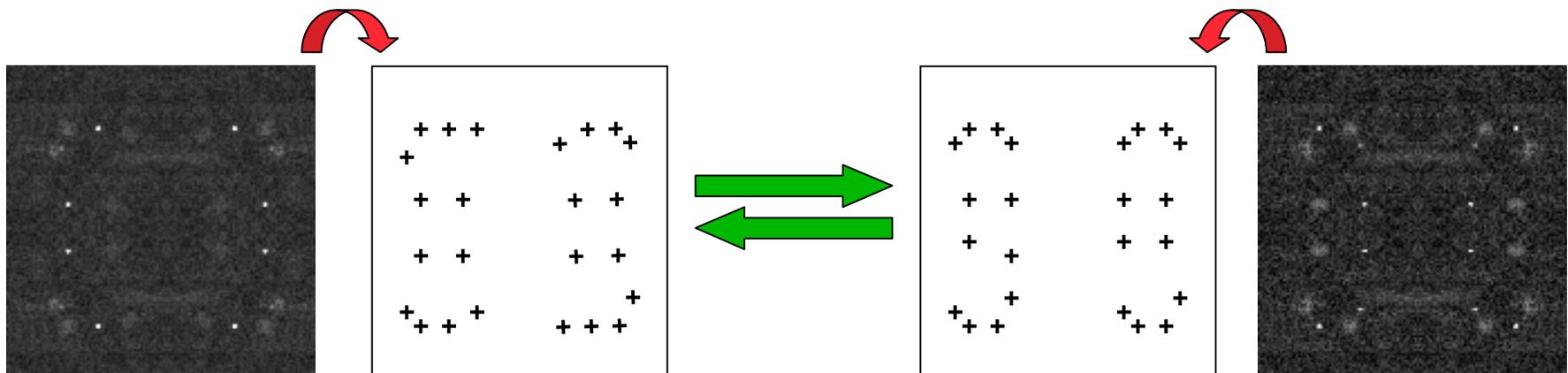
future

Choosing Main Registration Approach

- Use whole image data directly

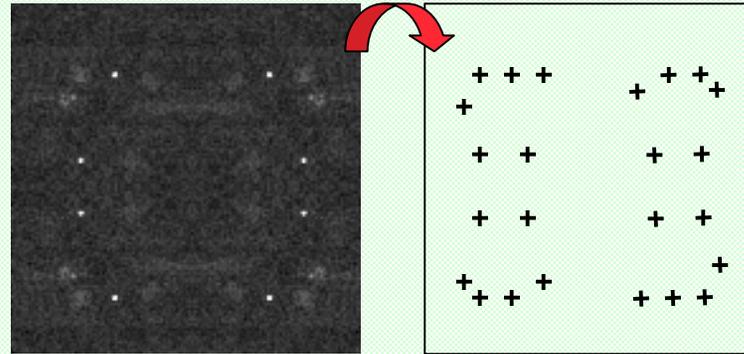


- Use features extracted from image

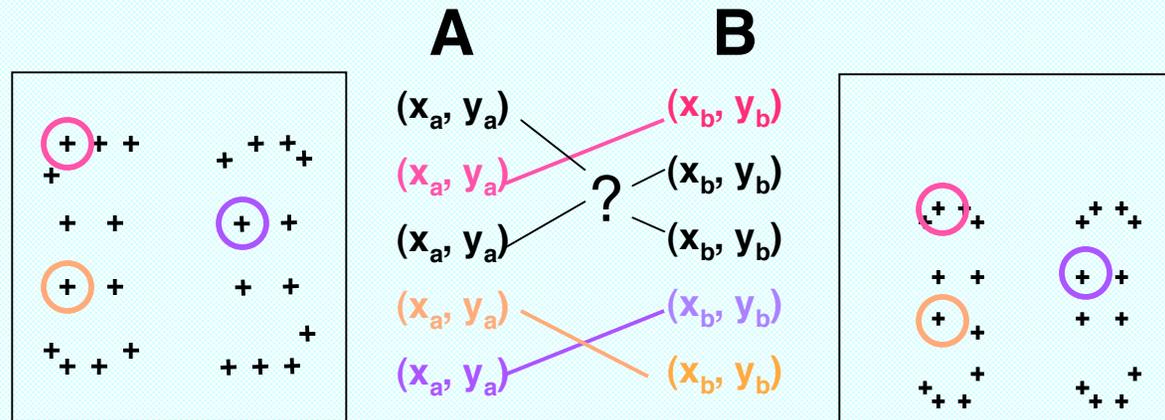


Standard Feature-Based Registration Steps

✓ 1. Feature Detection



★ 2. Feature Matching

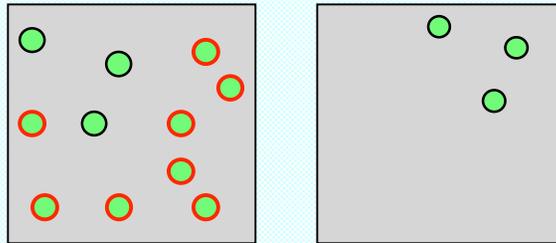


✓ 3. Finding Optimal Transformation

Find \mathbf{T} to minimize: $\|A - B\|$

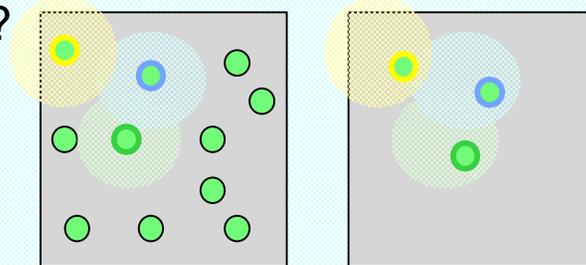
2) Feature Matching

- **Challenge:** high % of outlying points leads to *breakdown point*



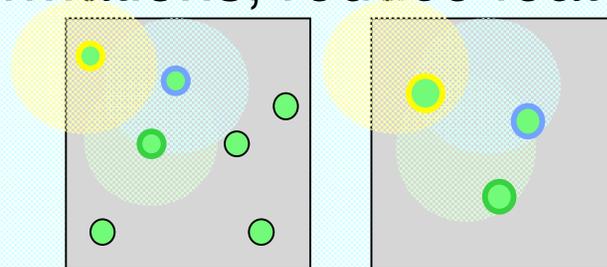
- Expecting a small transformation?

- Distances between features in different sets < distances between adjacent features in single set?



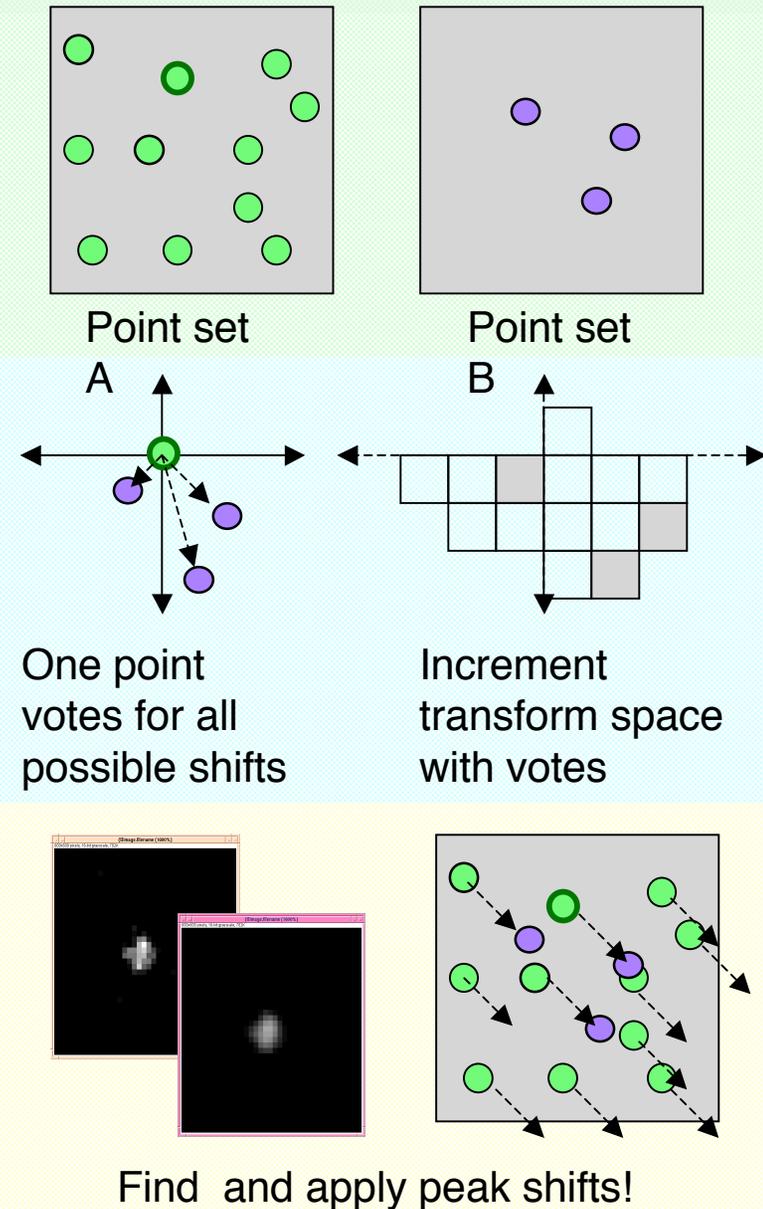
- Evaluate guess using expected matching %

- For larger transformations, reduce feature density using *a priori knowledge*



Feature Registration Without Feature Matching?

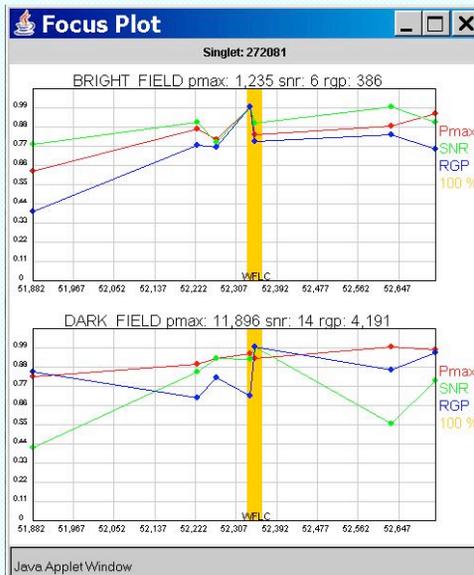
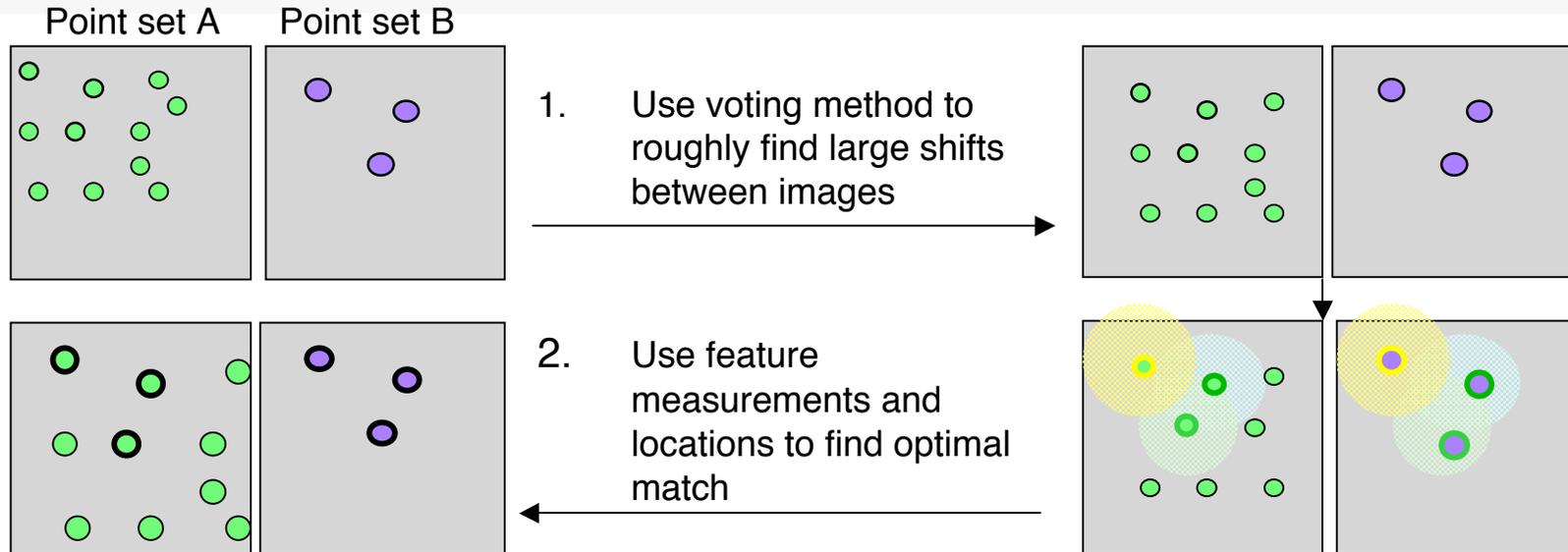
- *Points vote to concur* on the best transformation
- Comparing two points only supplies *x and y shift*
 - Similar feature consensus and clustering techniques use complex features to find rotation, scaling and shifts
- Adapt to use pairs of points from each image?



Current Final Optics Solution: Iterative Registration

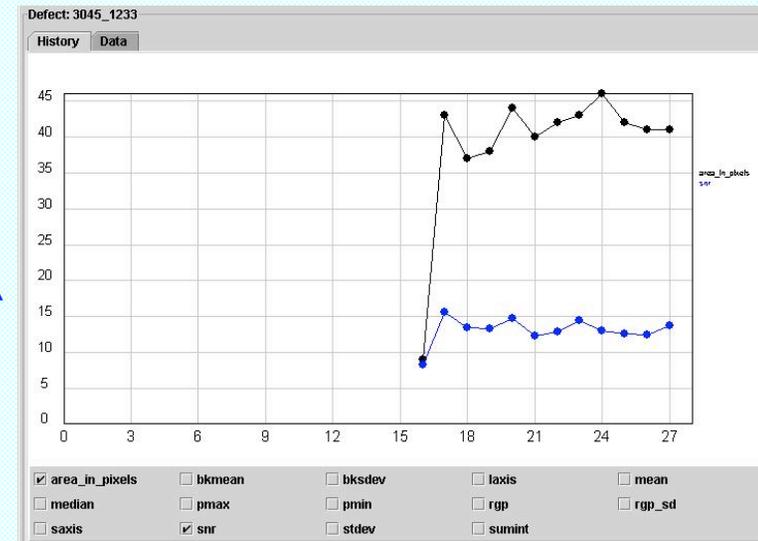


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Measurements of single feature

Optics through focus

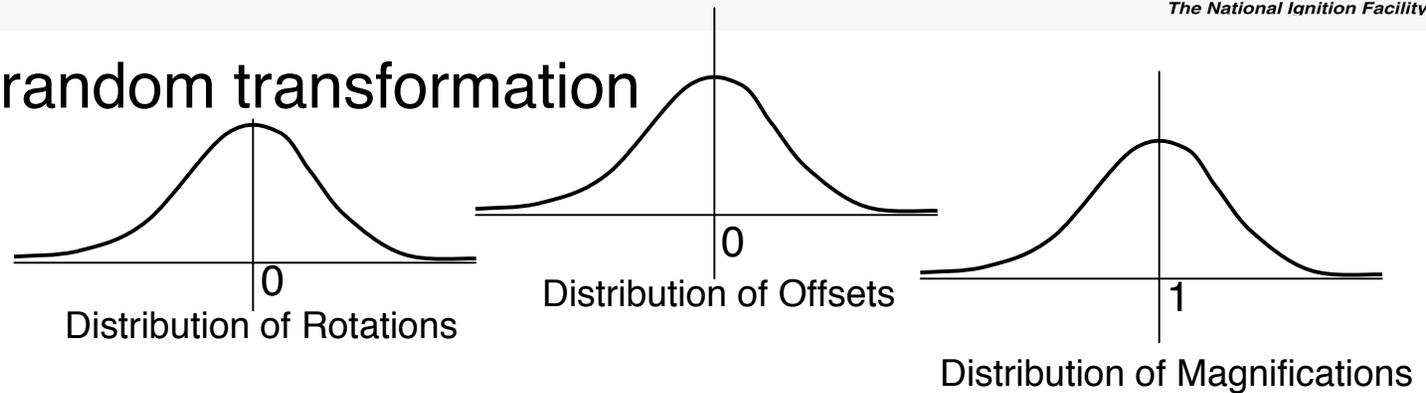


Measurements of single feature

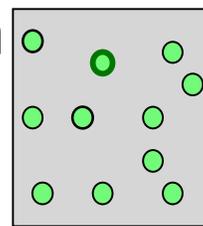
Dates of inspections

Probabilistic Transformation Without Feature Matching

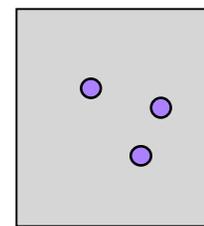
1. Choose random transformation



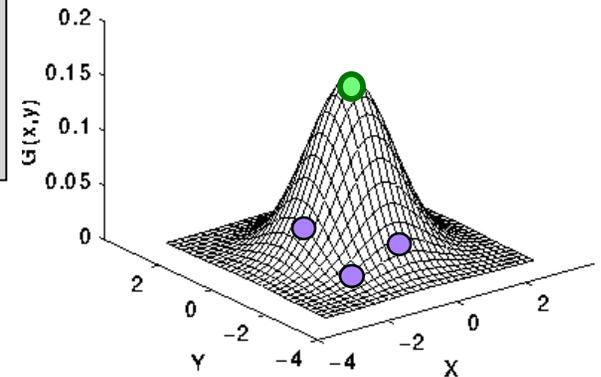
2. Evaluate transformation



Point set A



Point set B



3. Decide whether to accept new position

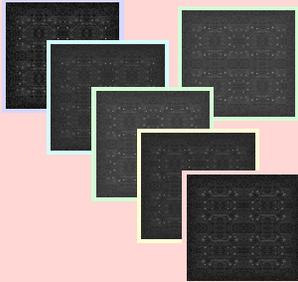
- If evaluation sum $>$ previous accept
- If evaluation sum $<$ previous accept with low probability

4. Iterate

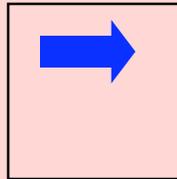
Conclusion: Registration Now and Then



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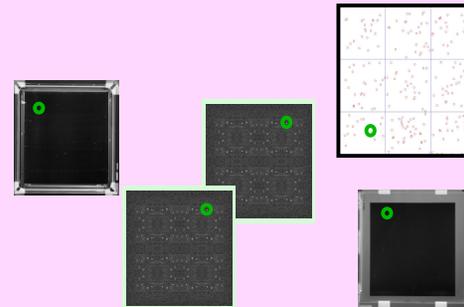
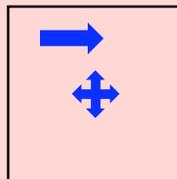


1. Vote for large shift

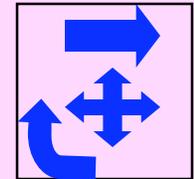


Evaluate Results

2. Matching & least squares finds small additional shifts and magnification

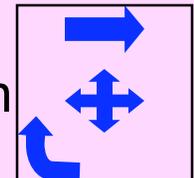


1. Vote for complete transformation using *subset of features*



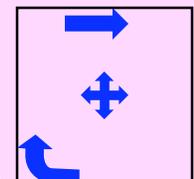
Evaluate Results

2. Probabilistic method: midsize transformation using *all features*



Evaluate Results

3. Matching & least squares finds small optimal transformation





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3) Finding Optimal Transformation

Finding shifts and scaling is a linear & separable problem:

- Two point sets:

$$\begin{array}{ll} \square & \square \\ (\mathbf{x}_{a1}, \mathbf{y}_{a1}) & (\mathbf{x}_{b1}, \mathbf{y}_{b1}) \\ (\mathbf{x}_{a2}, \mathbf{y}_{a2}) & (\mathbf{x}_{b2}, \mathbf{y}_{b2}) \\ (\mathbf{x}_{a3}, \mathbf{y}_{a3}) & (\mathbf{x}_{b3}, \mathbf{y}_{b3}) \end{array}$$

- Want to find optimal scaling and shifting in each direction:

$$\begin{pmatrix} \mathbf{x}_{a1} & 1 \\ \mathbf{x}_{a2} & 1 \\ \mathbf{x}_{a3} & 1 \\ \mathbf{x}_{a4} & 1 \end{pmatrix} \begin{pmatrix} \mathbf{x_scaling} \\ \mathbf{x_shift} \end{pmatrix} = \begin{pmatrix} \mathbf{x}_{b1} \\ \mathbf{x}_{b2} \\ \mathbf{x}_{b3} \\ \mathbf{x}_{b4} \end{pmatrix}$$

$$\downarrow$$

$$\mathbf{A}\vec{\mathbf{x}} = \mathbf{b}$$

$$\downarrow$$

$$\begin{pmatrix} \mathbf{x_scaling} \\ \mathbf{x_shift} \end{pmatrix} = (\mathbf{A}^T\mathbf{A})^{-1}\mathbf{A}^T \mathbf{b}$$

- To include rotation implement analytic least squares solution