

Developing Methods for Comparison of Cartridge Breechface Images

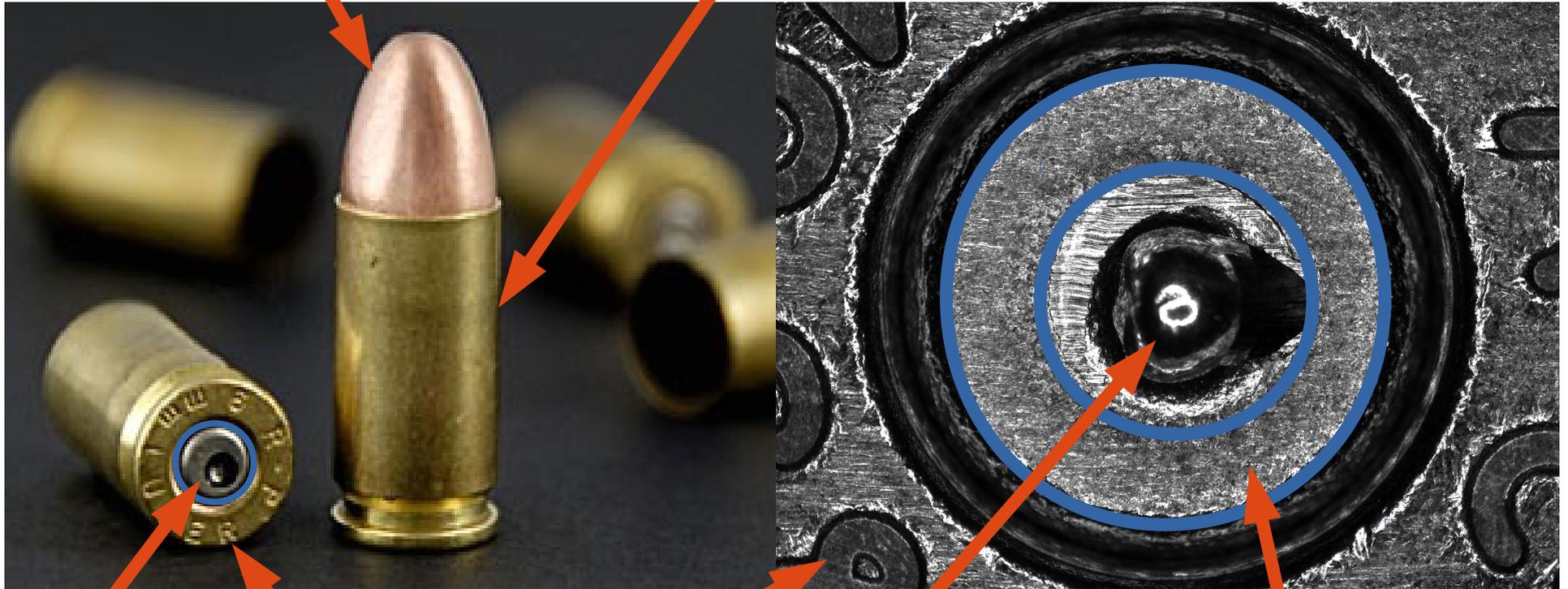


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Bullet

Cartridge case



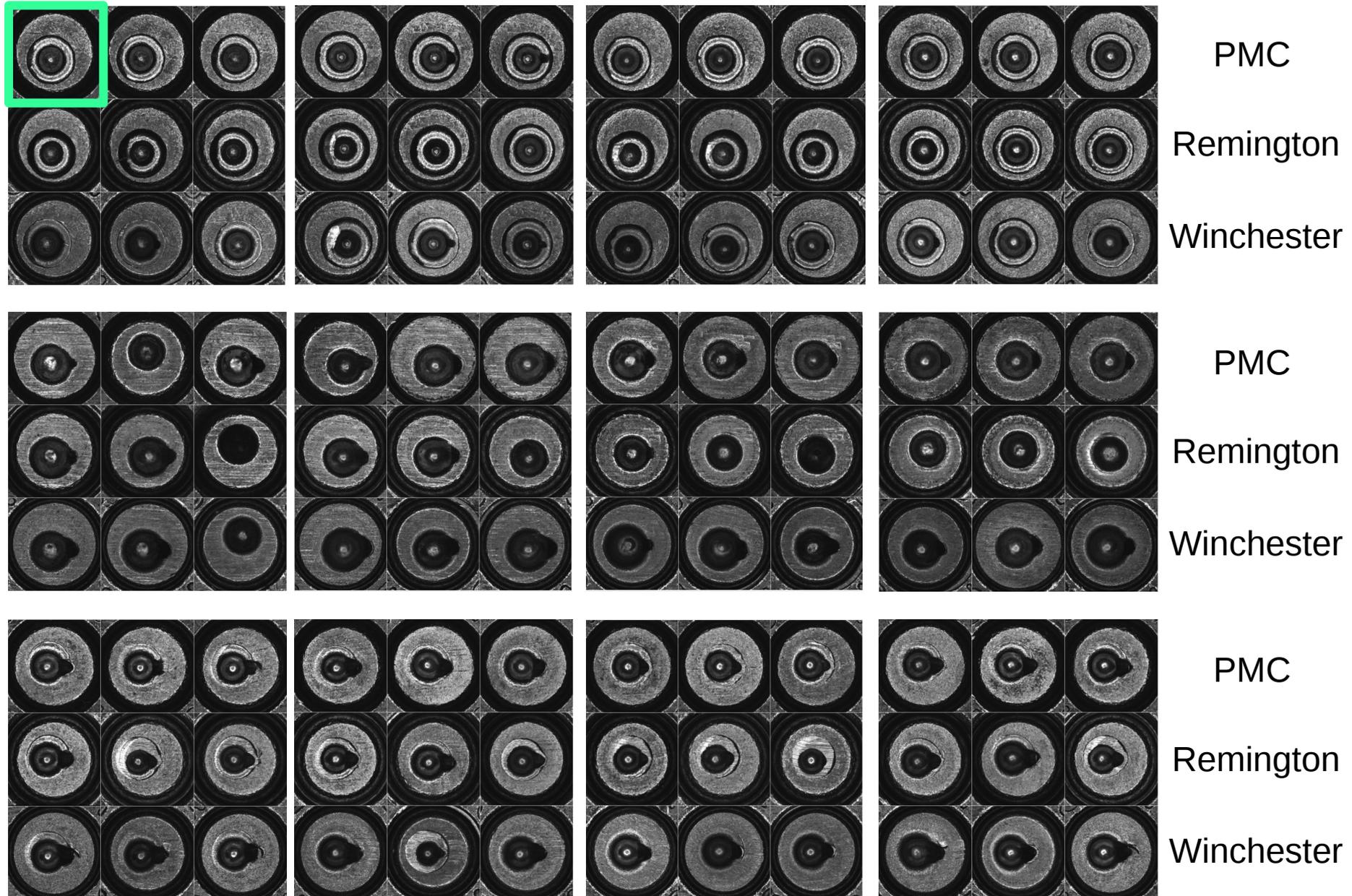
Primer

Headstamp

Firing pin impression

Breechface marks

108 images, 12 guns (9 images per gun)



This Project

- Focus on 2D images
- Build on published methods for comparing images
- Quantify confidence in making any statement of a match

Steps for One Pairwise Comparison

1) Automatically select breechface marks

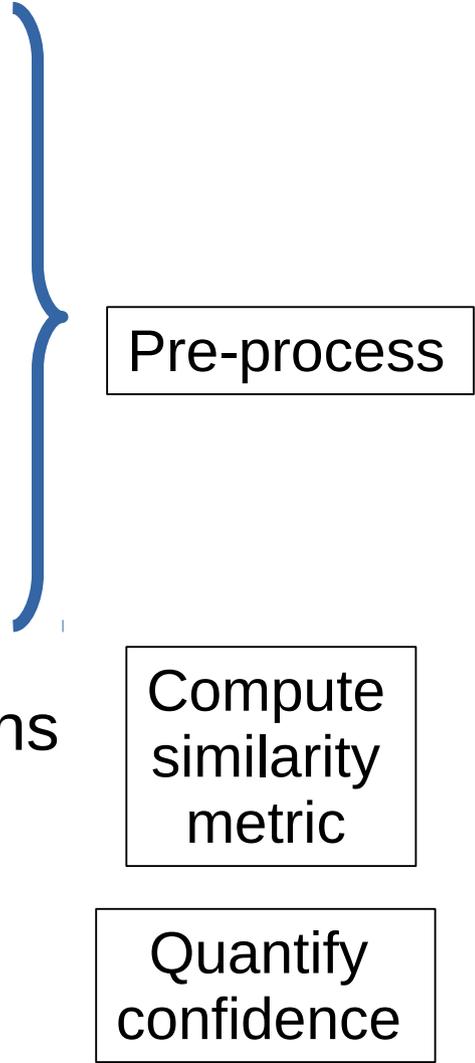
2) Adjust for differences in brightness (leveling image)

3) Remove circular symmetry

4) Outlier removal and filtering

5) Maximize correlation by translations and rotations

6) Produce p-value which serves as a measure of uncertainty

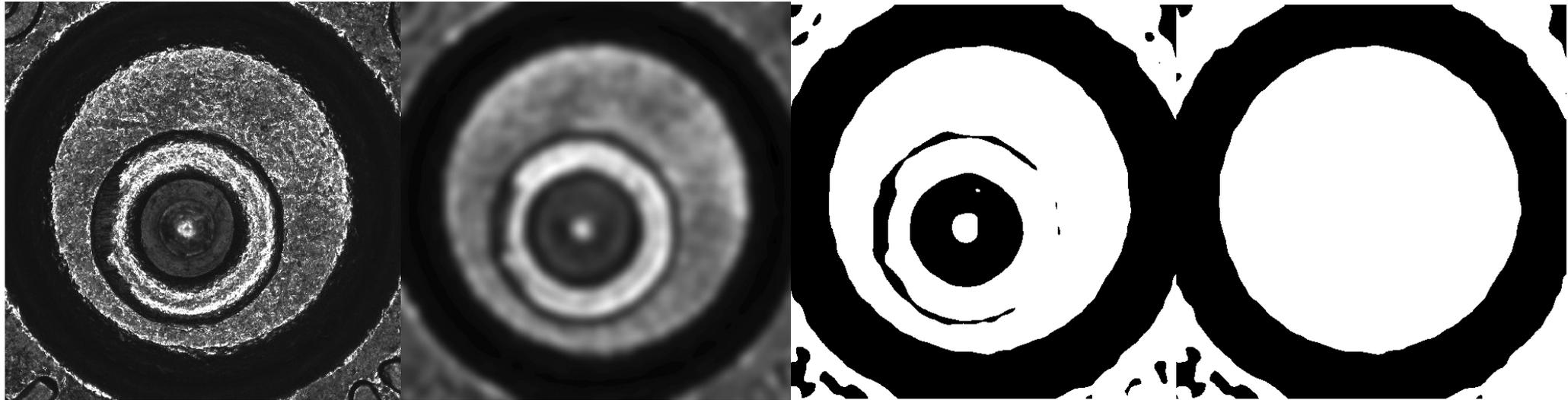


Pre-process

Compute
similarity
metric

Quantify
confidence

Step 1: Select Breechface Marks

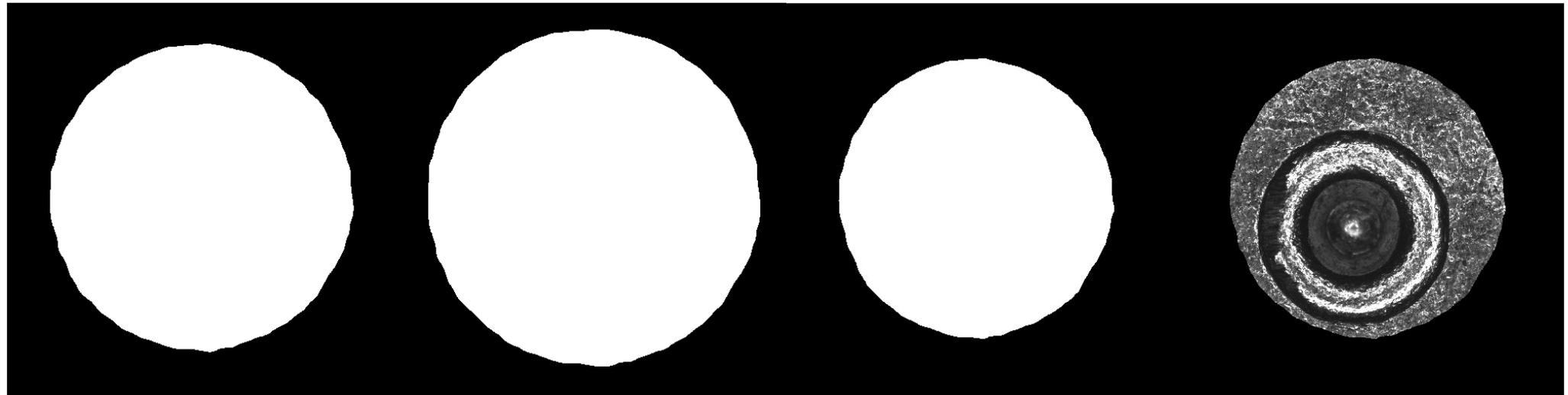


Original image

Apply a Gaussian filter

Histogram equalization
with 2 bins

Flood fill

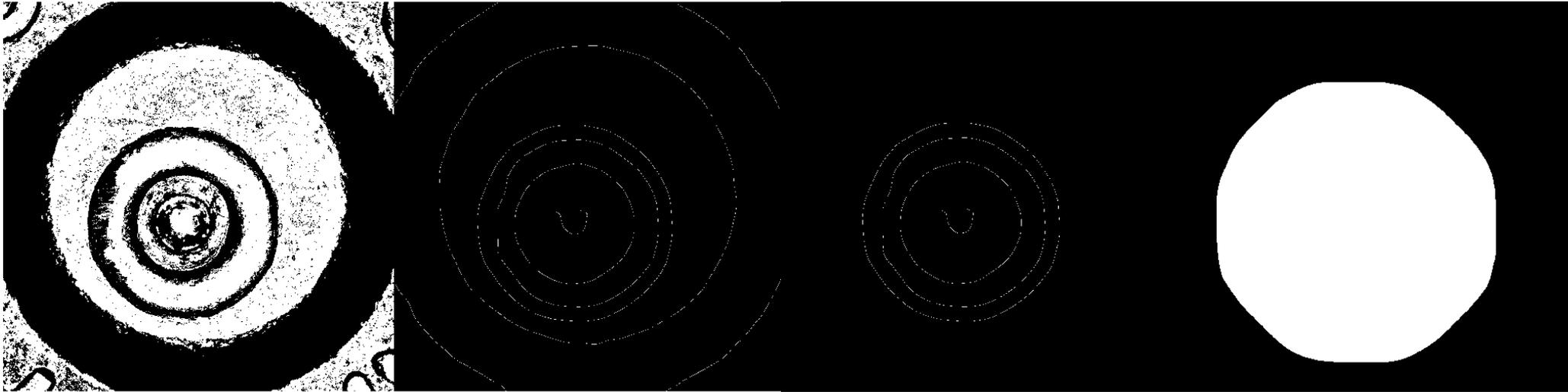


Select center region

Dilate

Erode

Selected
primer region

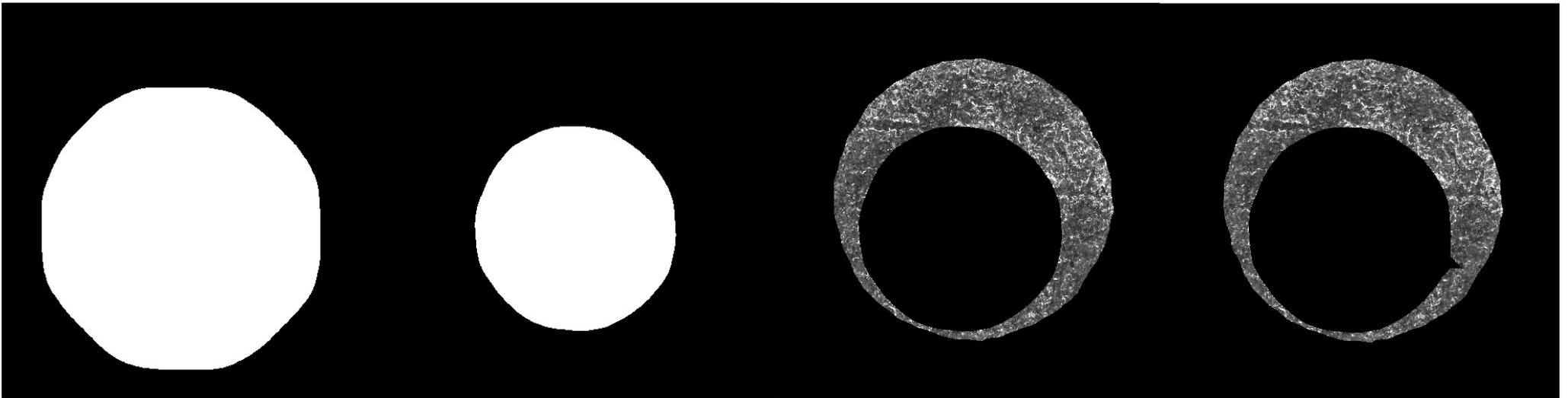


Histogram equalization
with 2 bins

Canny edge detector

Only consider
primer region

Dilate



Flood fill

Erode

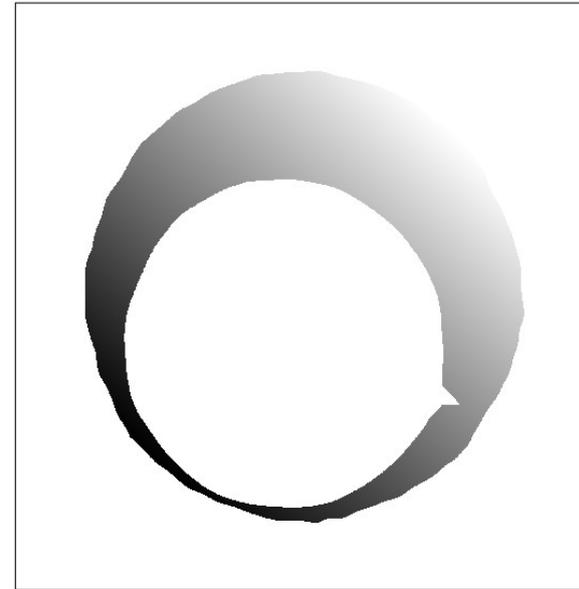
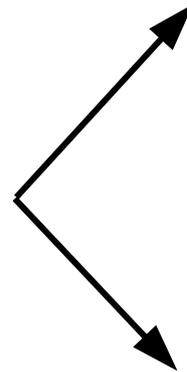
Currently selected firing
pin region

Second pass

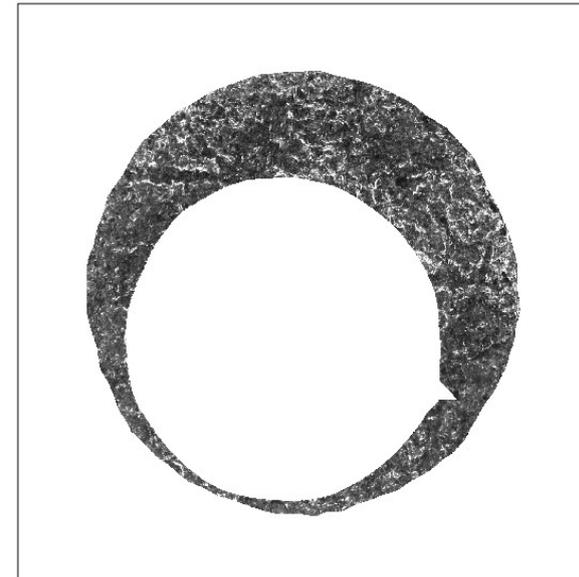
Step 2: Level Image



Original



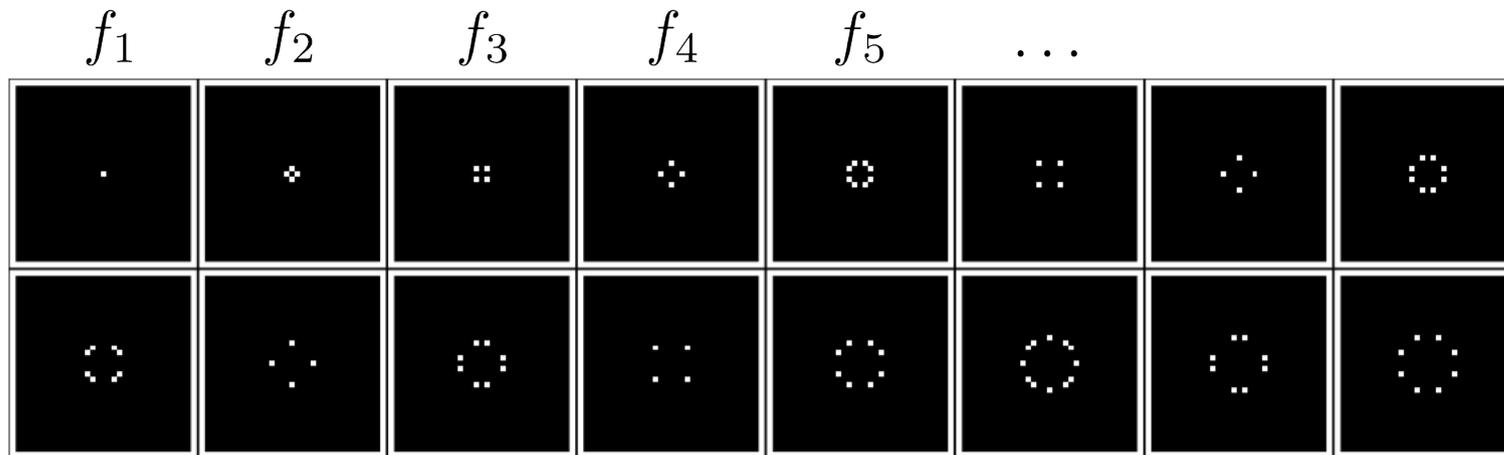
Fitted Plane



Residuals

Step 3: Remove Circular Symmetry

Decompose each image into a linear combination of circularly symmetric basis

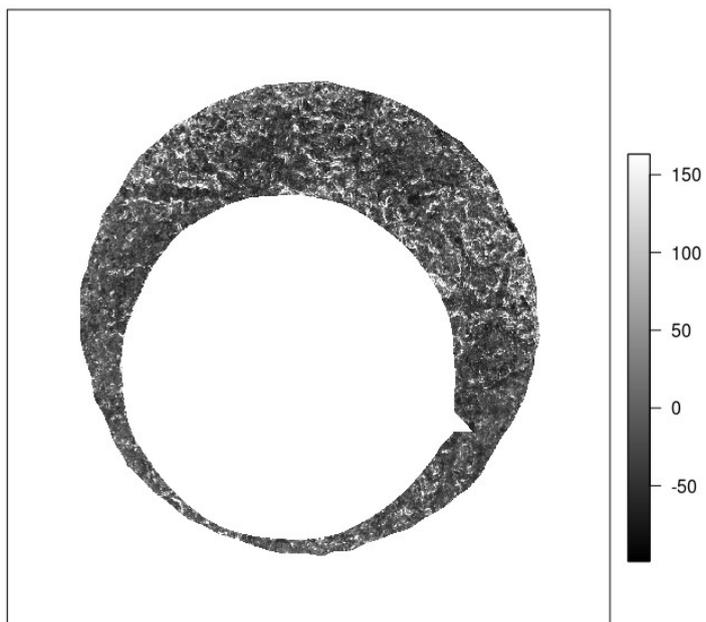


$$Image(i, j) = \sum_{k=1}^K \beta_k f_k(i, j) + \epsilon(i, j)$$

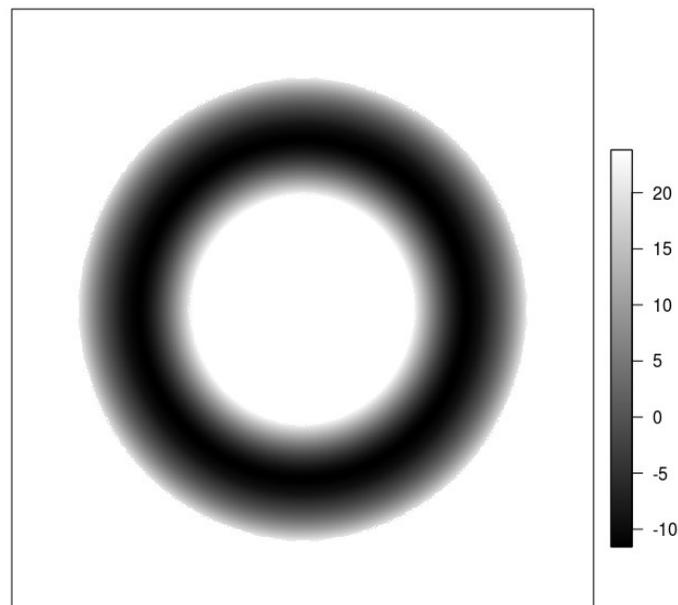
- K is the number of basis functions,
- f_k is the k th basis function, and
- β_k is the basis function coefficient for f_k .

Captures
circular
symmetry

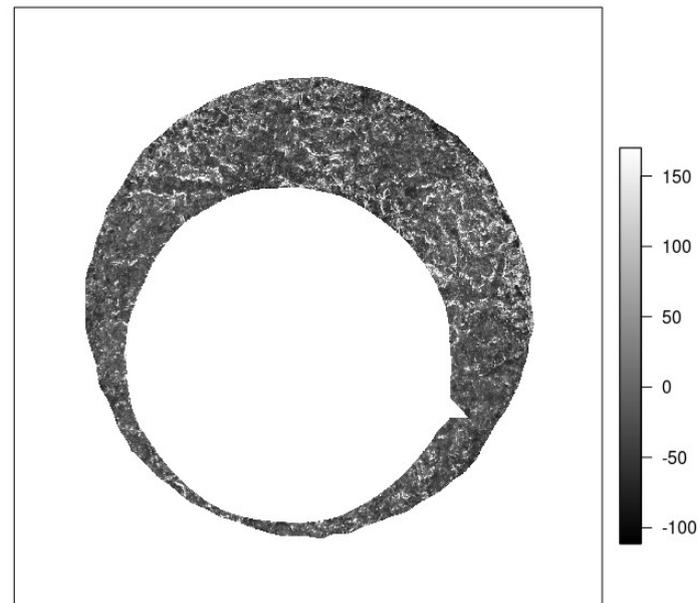
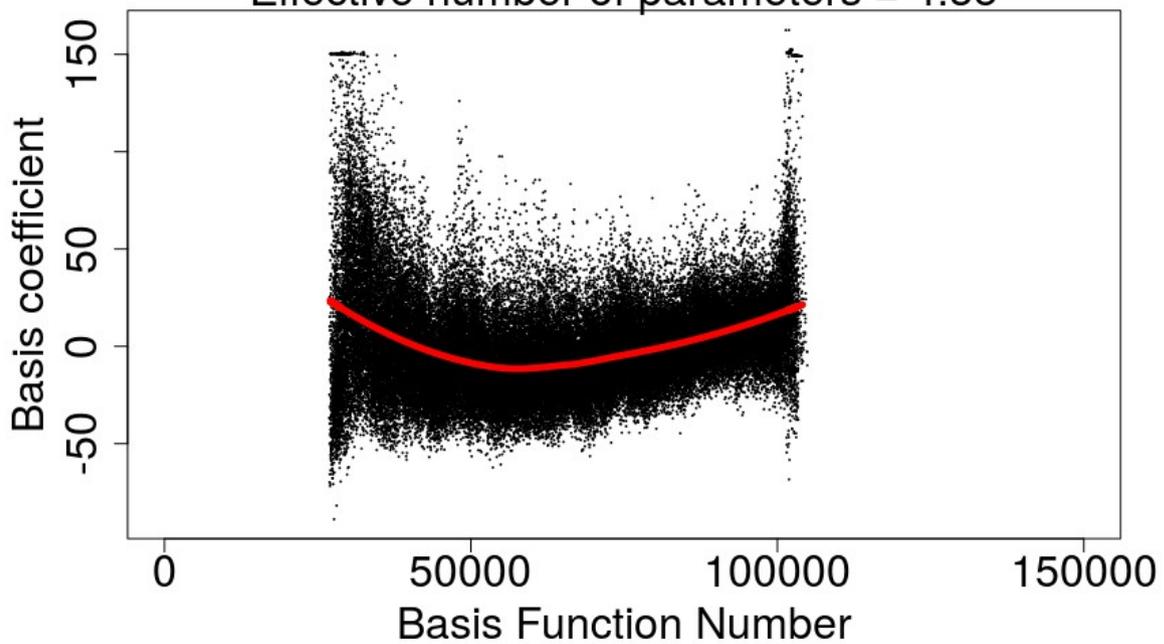
Residuals from previous step



Fitted Circularly Symmetric



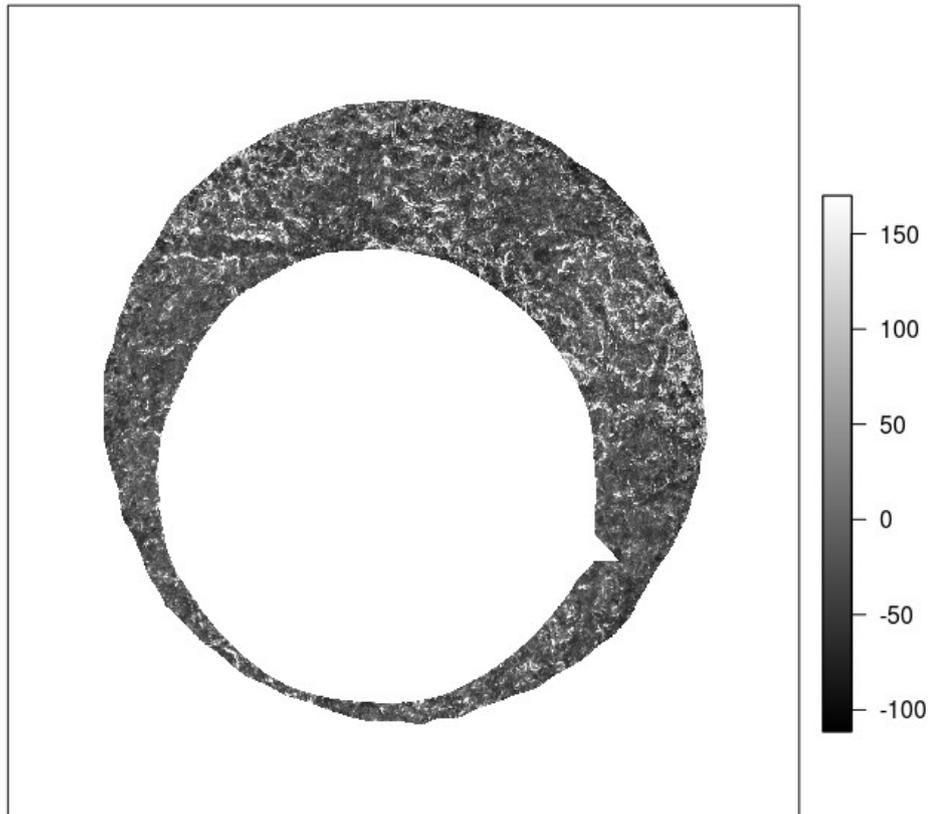
Coefficients for Each Basis Function
Effective number of parameters = 4.35



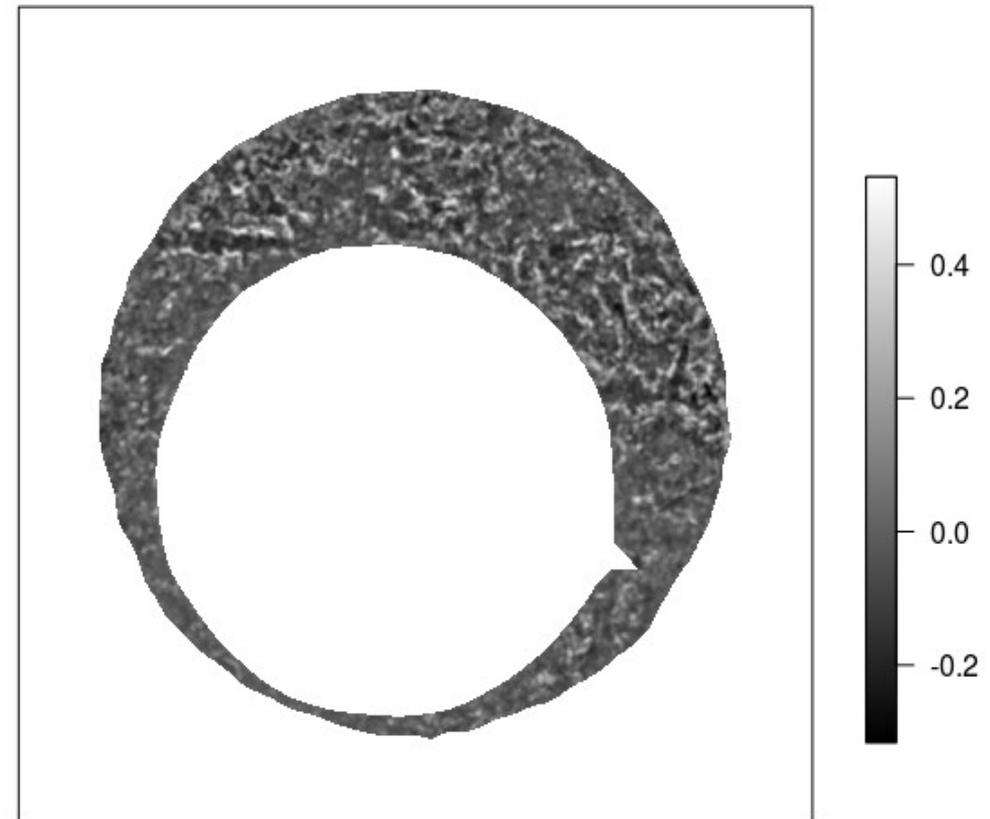
Residuals

Step 4: Outlier Removal and Filtering

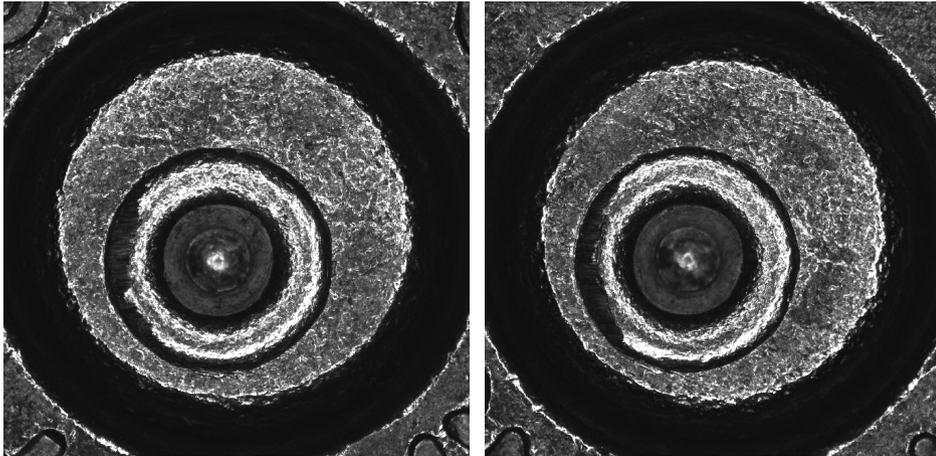
Residuals from Previous Step



After All Pre-processing

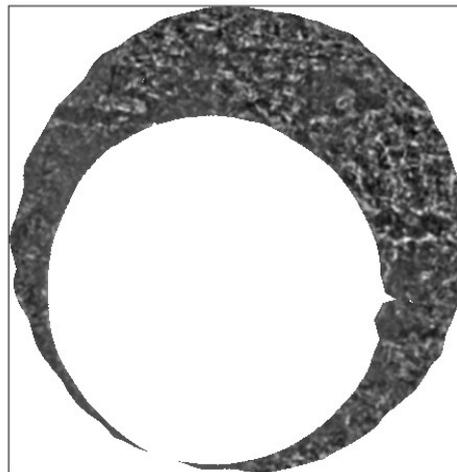


Step 5: Maximize Correlation by Translations and Rotations



Reference Image

Comparison Image



For each rotation angle,

Translations

$$CCF(I_1, I_2) = \frac{\sum_{i,j} I_1(i, j) I_2(i + dx, j + dy)}{\sqrt{\sum_{i,j} I_1(i, j)^2} \sqrt{\sum_{i,j} I_2(i, j)^2}}$$

$$\theta^* = -15^\circ$$

$$CCF_{max} = .38$$

Step 6: Perform Hypothesis Test

H_0 : Images are not a match (not from the same gun)

H_A : Images are a match

Test statistic: CCF_{\max}

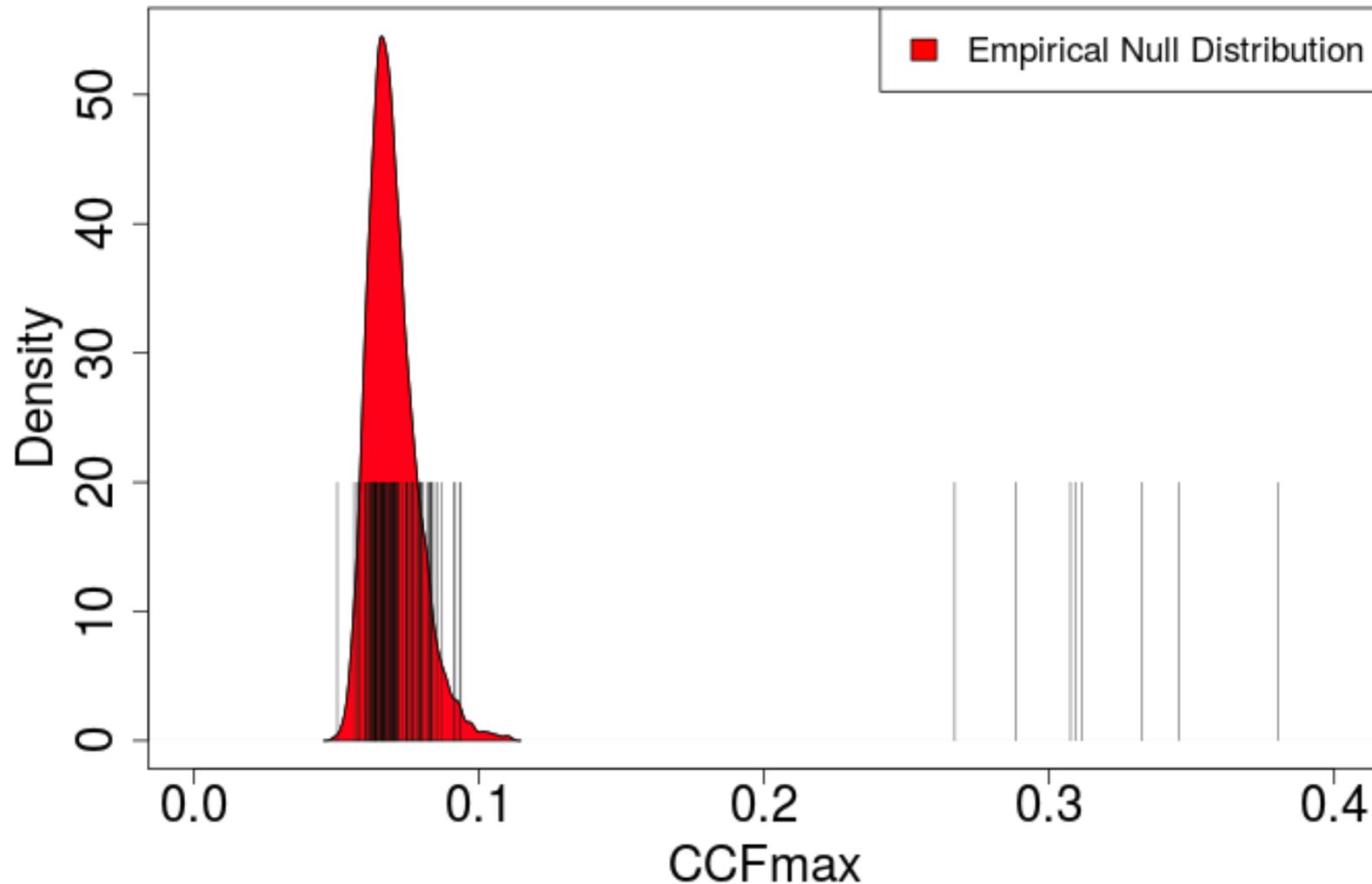
Distribution under H_0 : Empirical distribution of known non-matches

Interpretation of p-value: Probability of observing a larger value of CCF_{\max} , under the assumption that the two images are not a match.

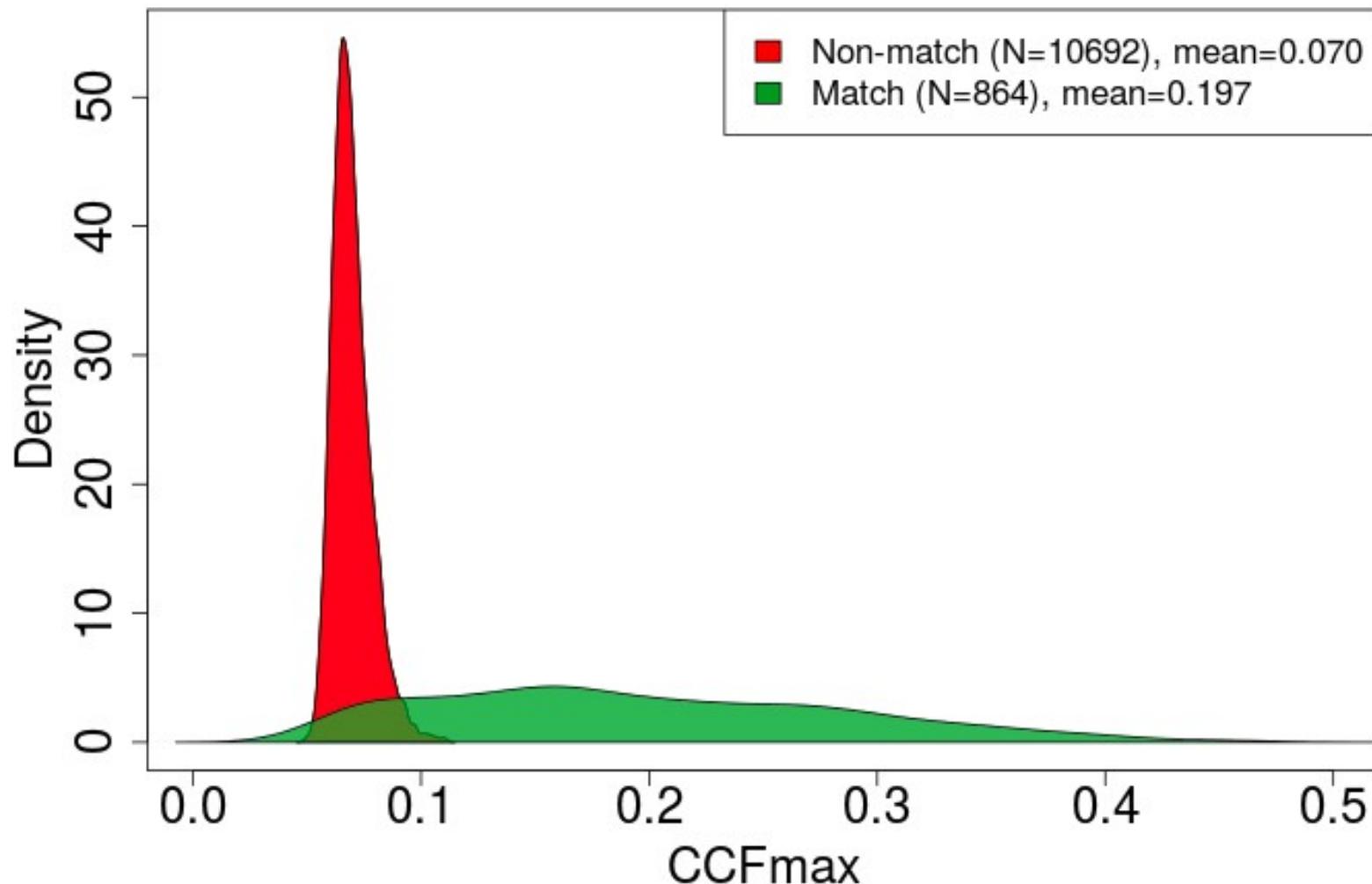
“If these two images are not a match, the probability of observing $CCF_{\max} > .38$ is $<.01\%$.”

All Pairwise Comparisons for 1 Image

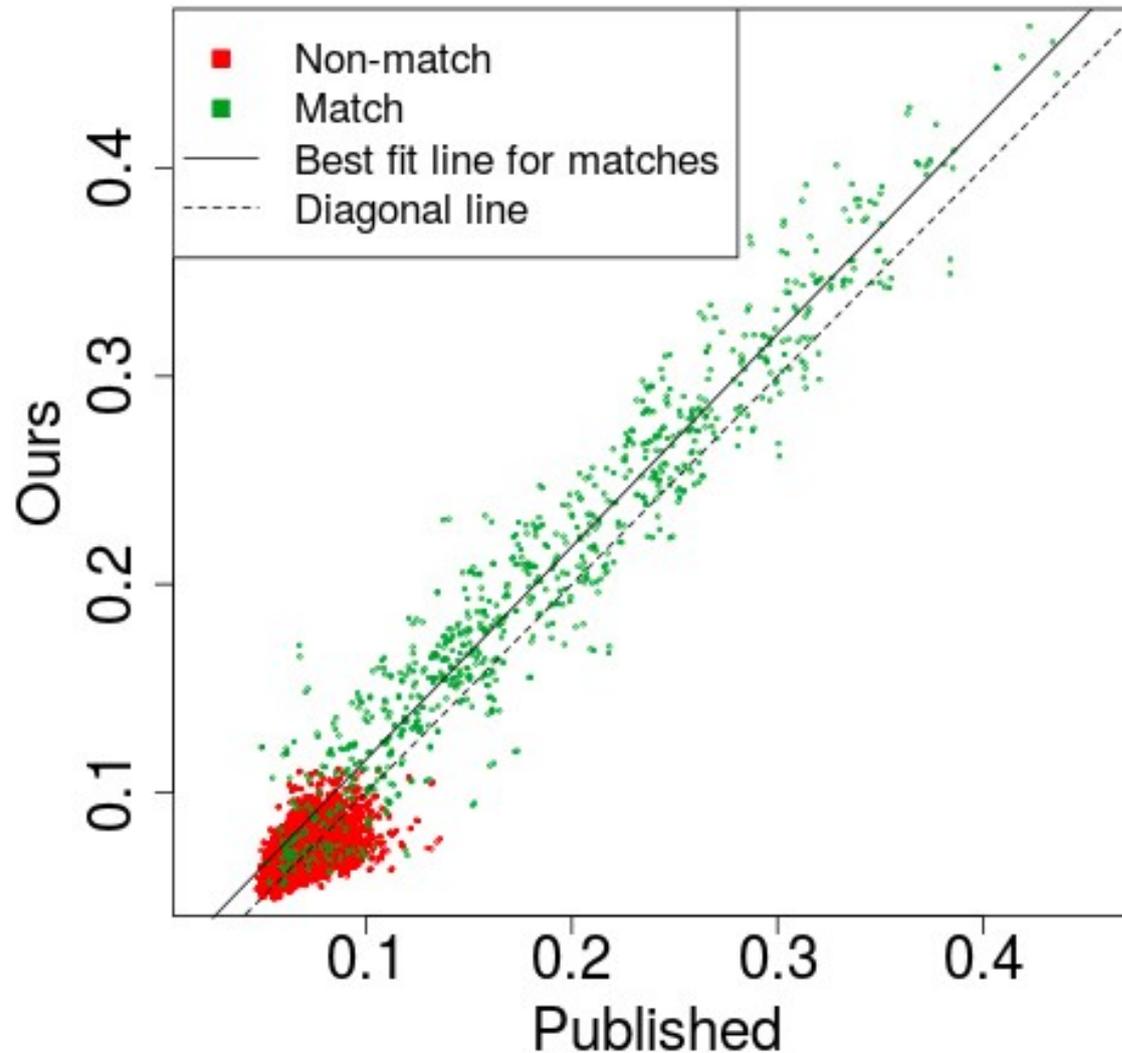
CCFmax for 107 pairwise comparisons



Distribution of CCF_{\max} for All Pairwise Comparisons in Dataset



Our Method Reduces CCF_{\max} of True Non-matches

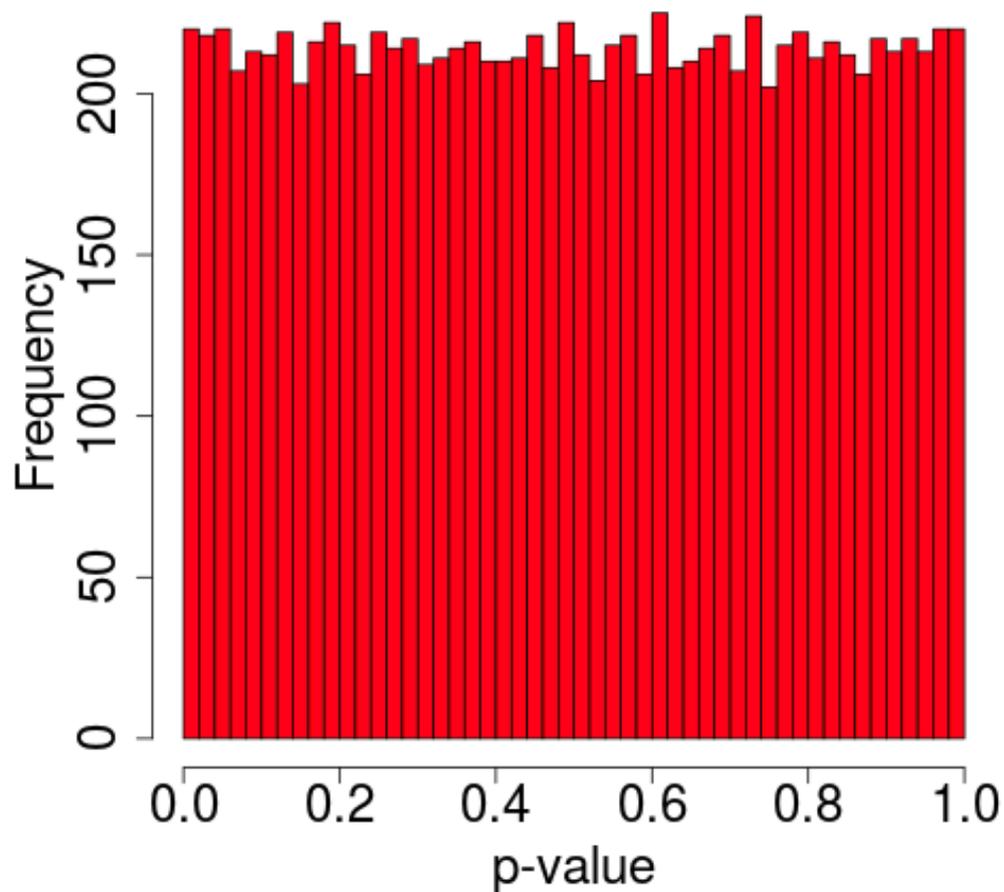


Roth, Carriveau, Liu, Jain (IEEE, 2015)
Vorburger and co-authors (NISTIR, 2007)

Distribution of p-values for All Pairwise Comparisons in Dataset

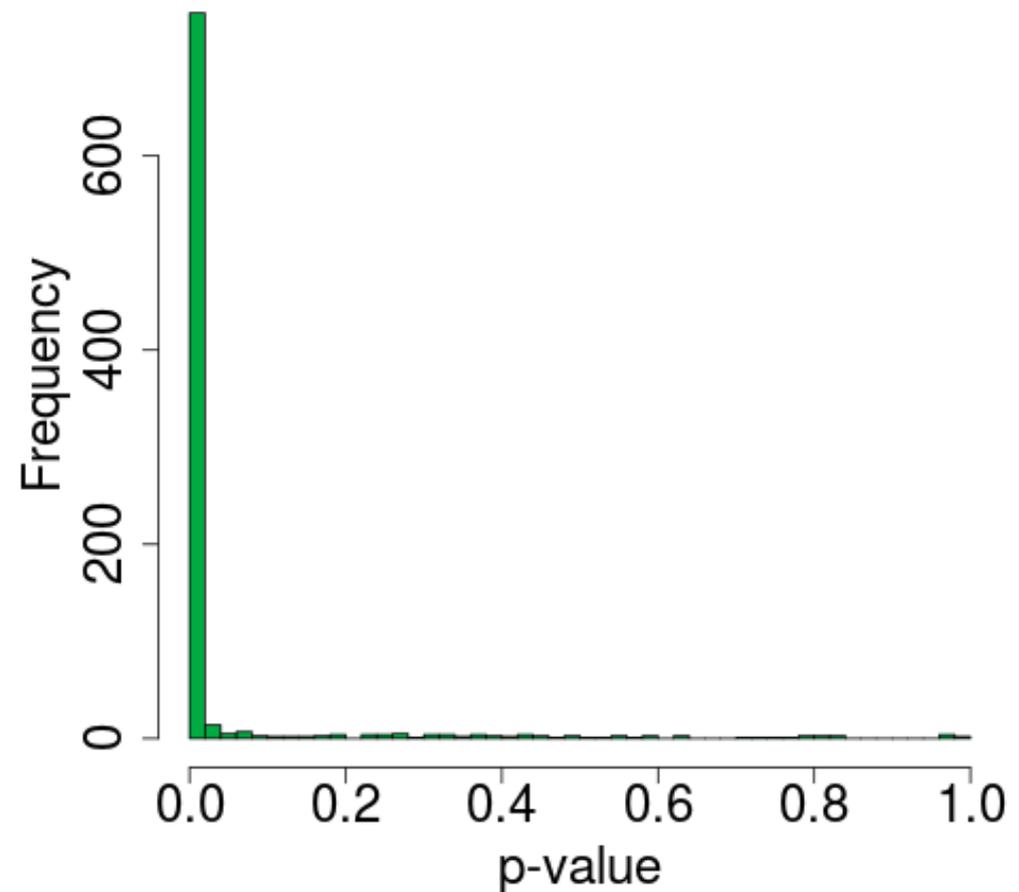
Histogram of p-values for non-matches

N=10692, mean=0.500



Histogram of p-values for matches

N=864, mean=0.049



Thank you!

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