

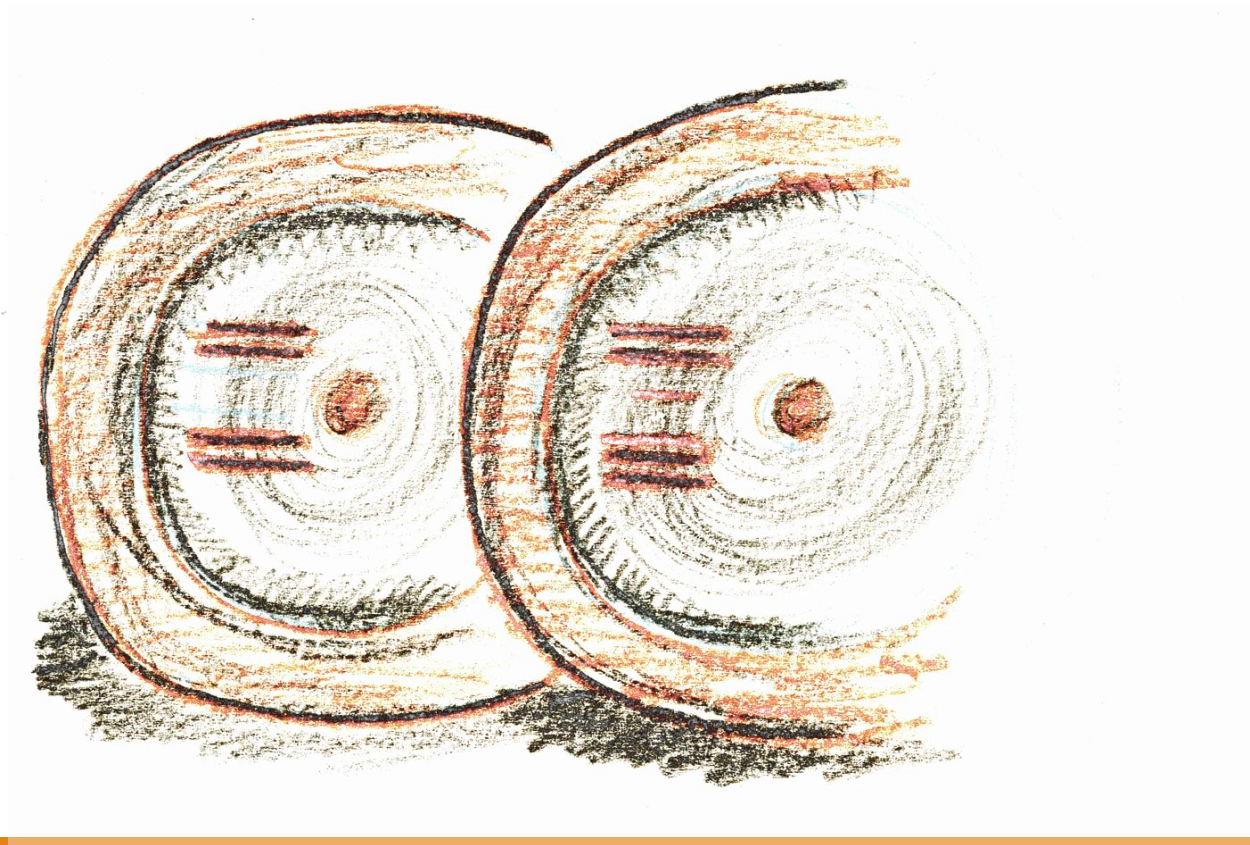
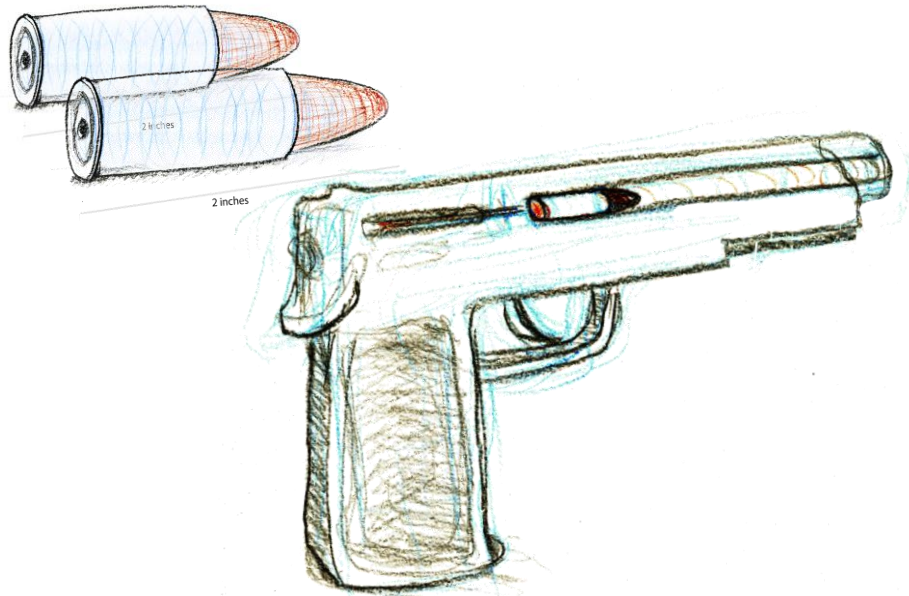
The Same Smoking Gun?

Approaches and Implementation

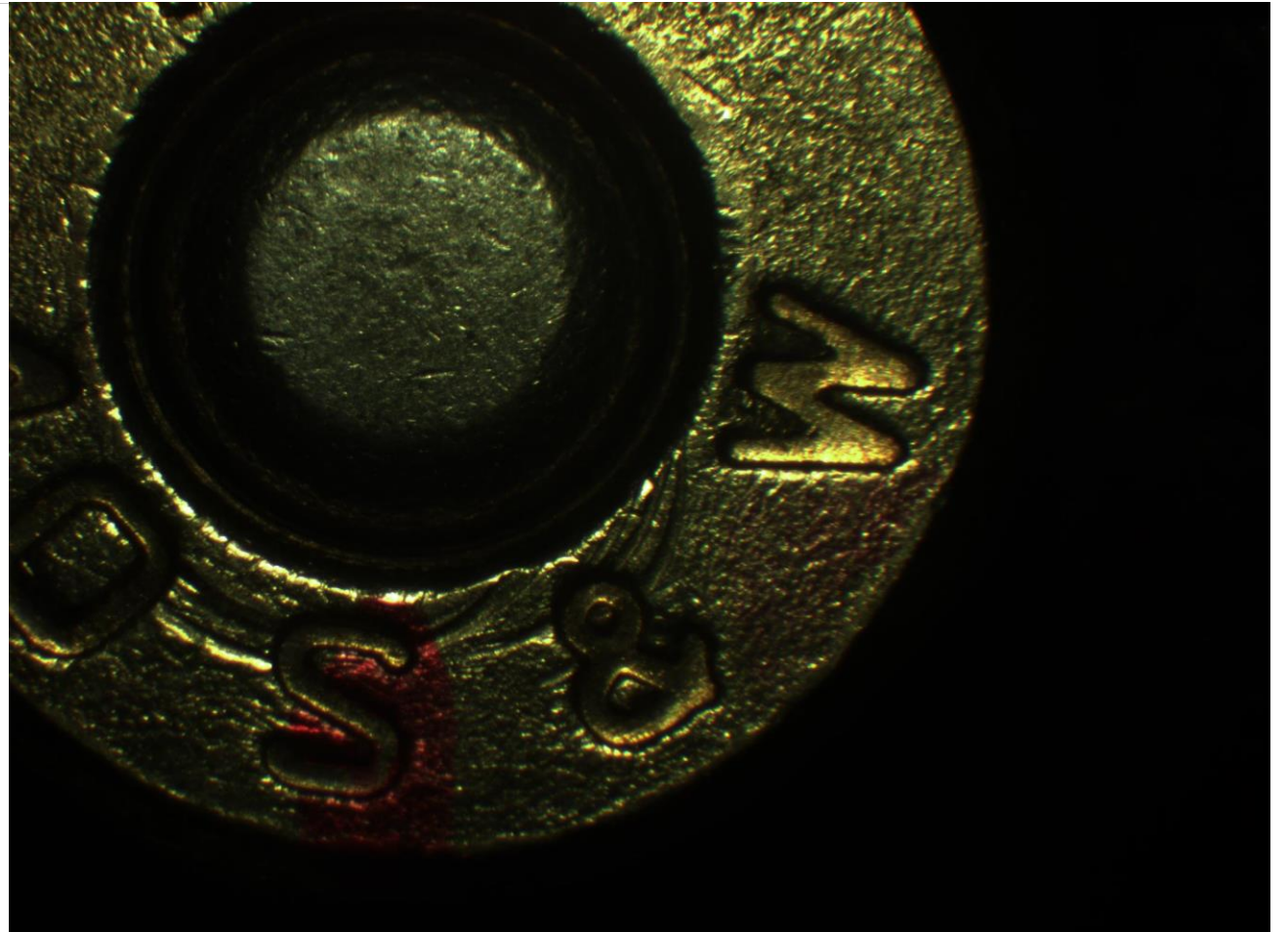
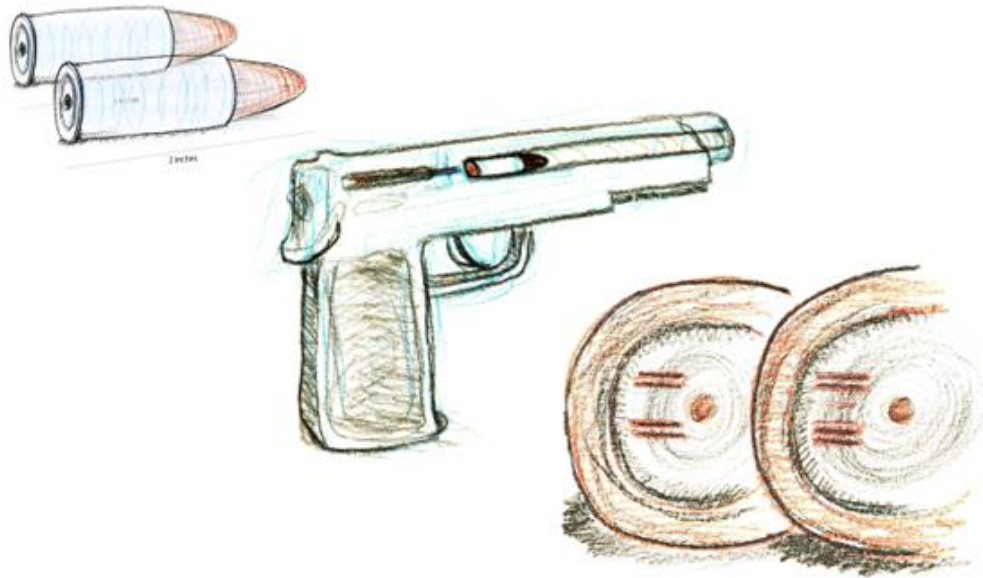
August 2016

Munir Winkel, GStat

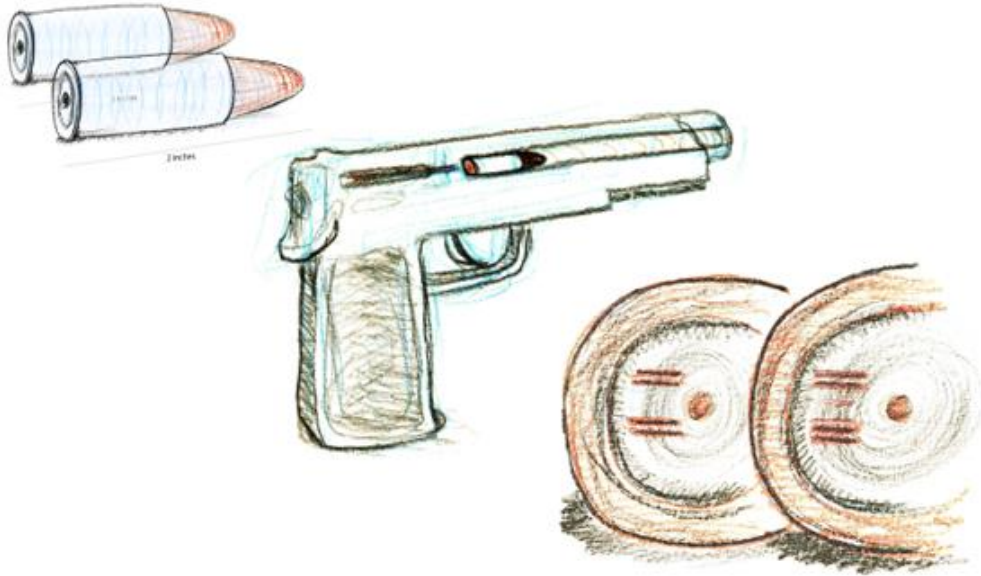
Introduction



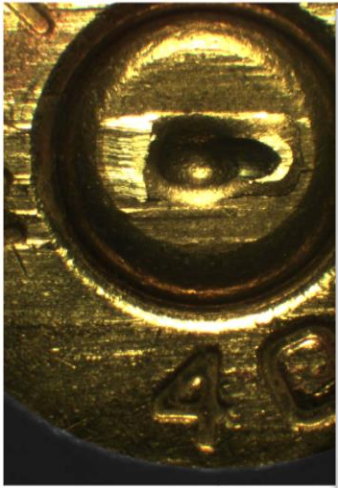
Introduction



Introduction

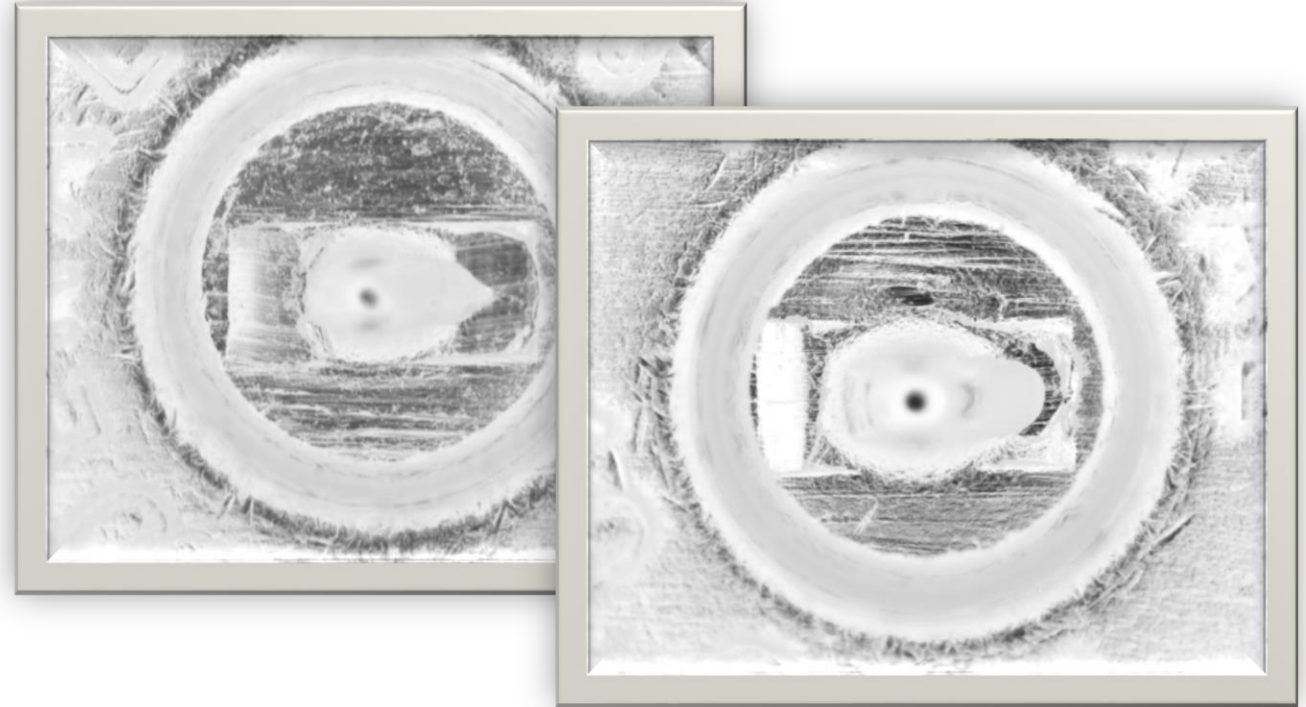


Introduction



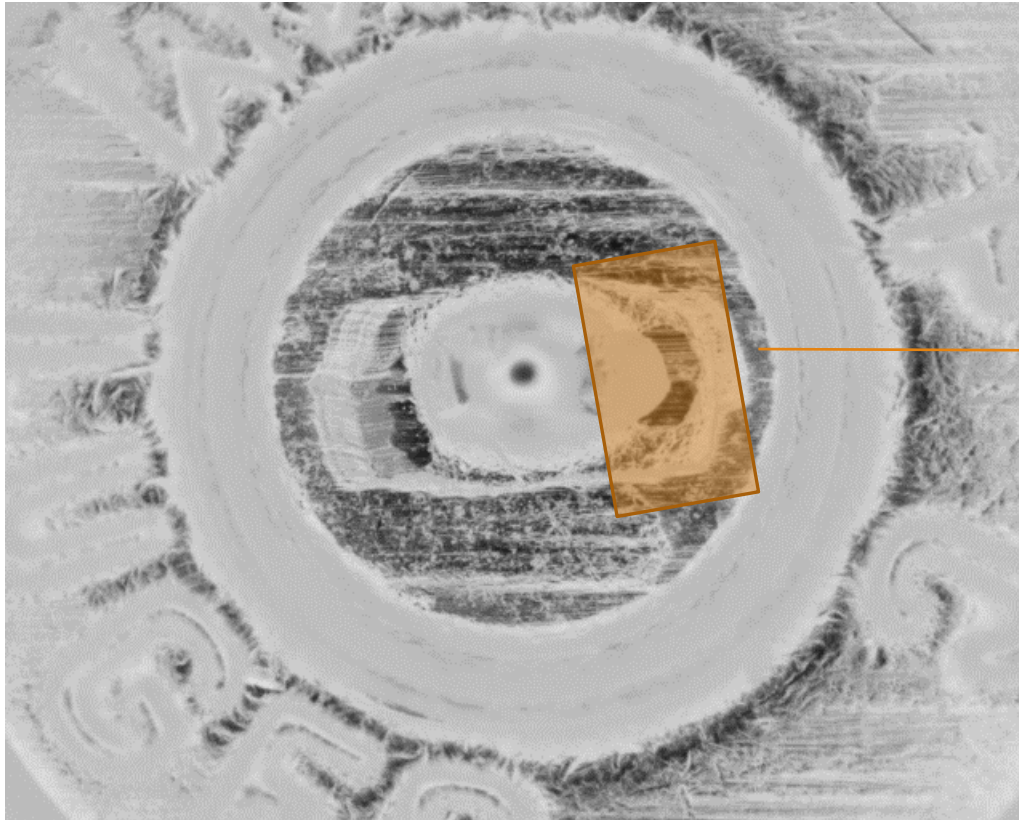
Natural lighting produces highlights and shadows

Introduction

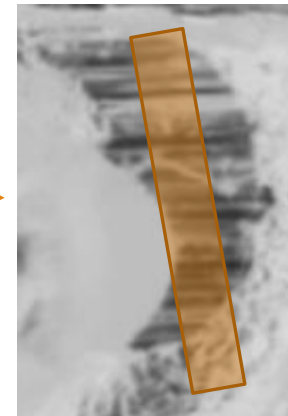


Infrared lighting produces neither highlights nor shadows

Initial Approach: Barcodes



Begin with: an infrared image



Convert to: a vector of 0s and 1s (a barcode)

Determine: how "close" these bullet cartridges (i.e. barcodes) are to each other

Initial Approach: Barcode Distance

$$\text{symmetric KL} = \frac{1}{2} \sum_i (p_i - q_i) \ln \left(\frac{p_i}{q_i} \right)$$

$$\text{local averaging } p_i = \frac{1}{3} \sum_{j=i-1}^{i+1} x_j \quad \text{for } 2 \leq j \leq n-1$$

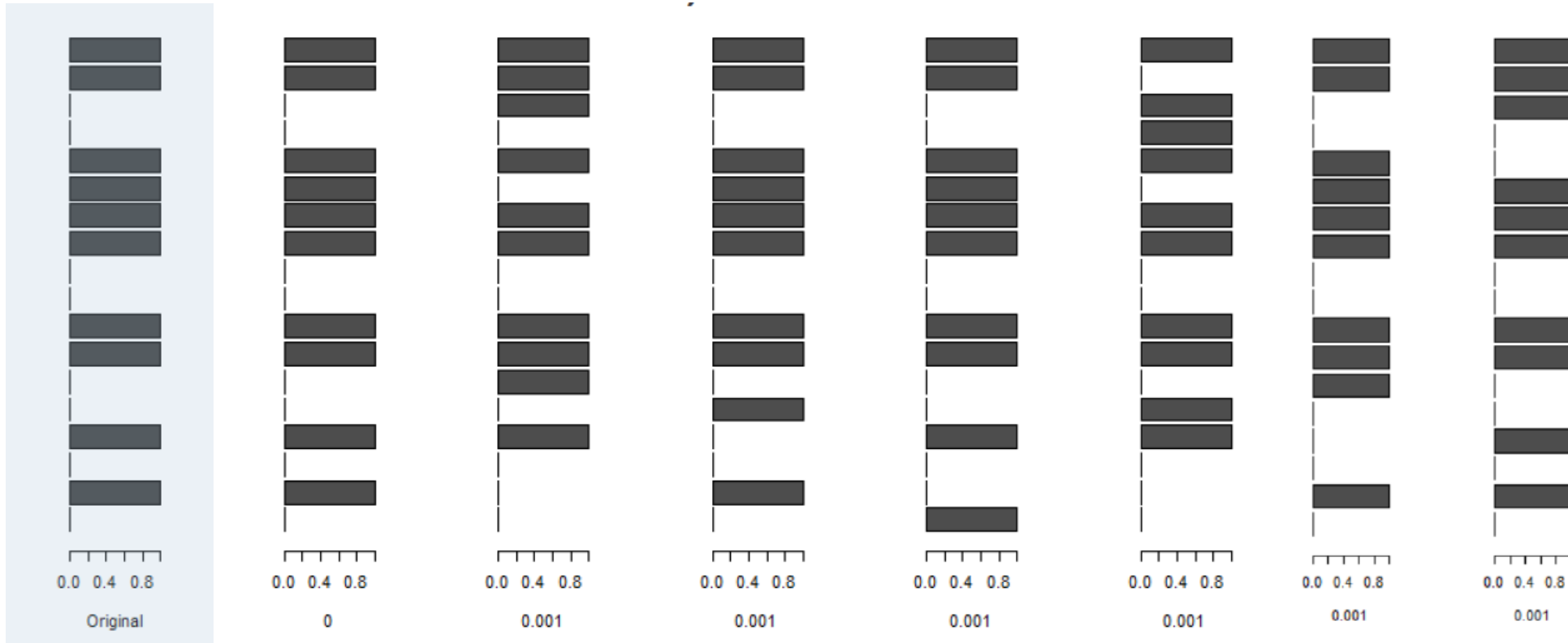
Initial Approach: Barcode Distance

Example

Original		Local Average	
P	Q	P	Q
0	0	1/2	0*
1	0	1/3	1/3
0	1	1/3	2/3
0	1	0*	2/2

$$\sum_i \frac{1}{2} (P_i - Q_i) \ln \left(\frac{P_i}{Q_i} \right) = 2.05$$

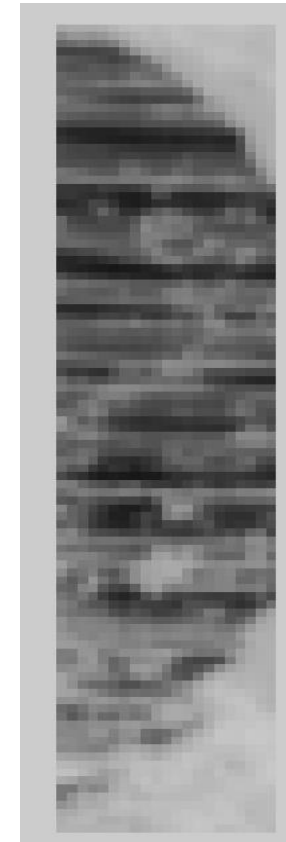
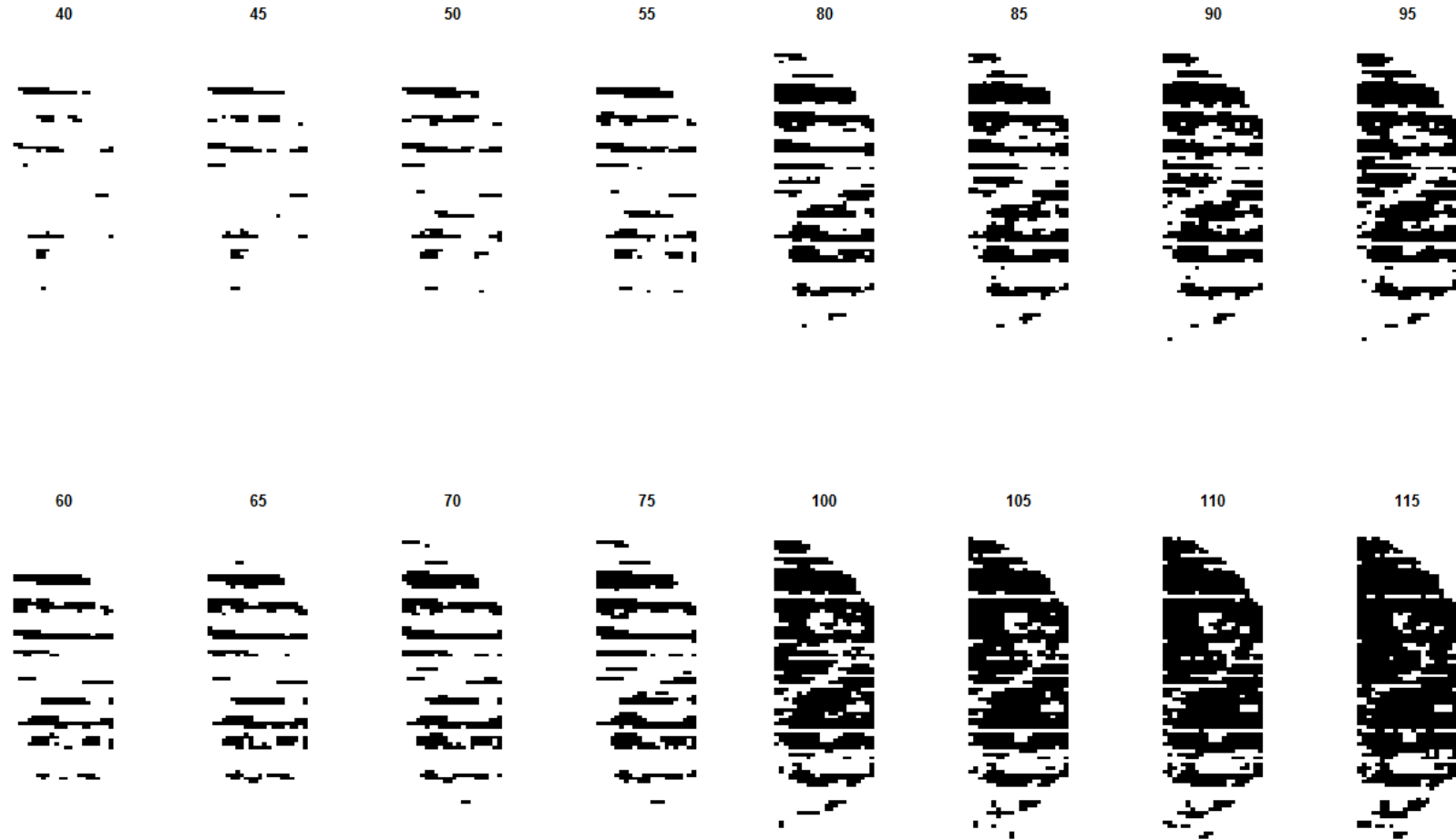
Initial Approach: Barcode Distance



Simulating 10,000 barcodes as Bernoulli(18,0.4)

Looking for the smallest Kullback-Leibler divergence

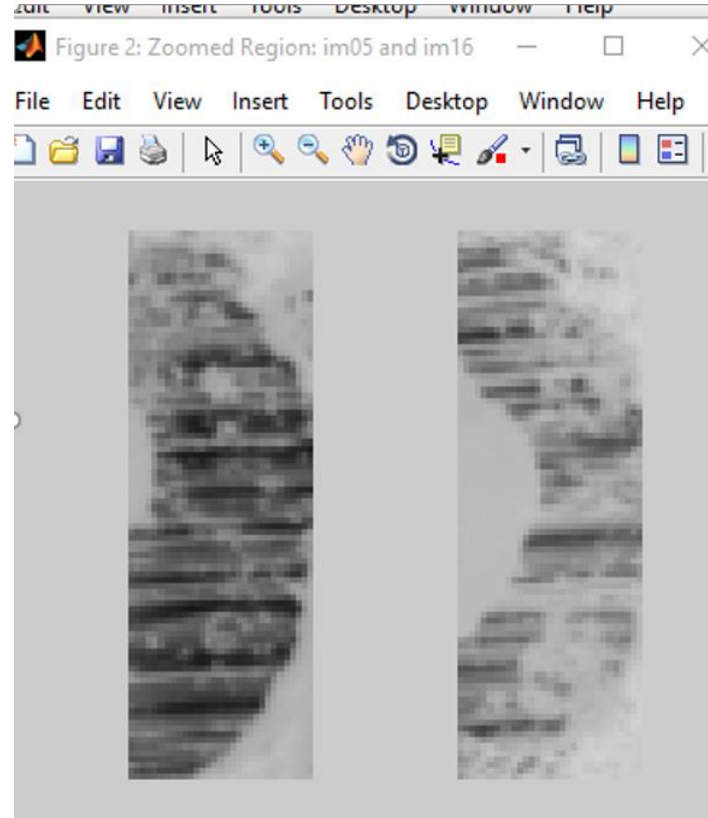
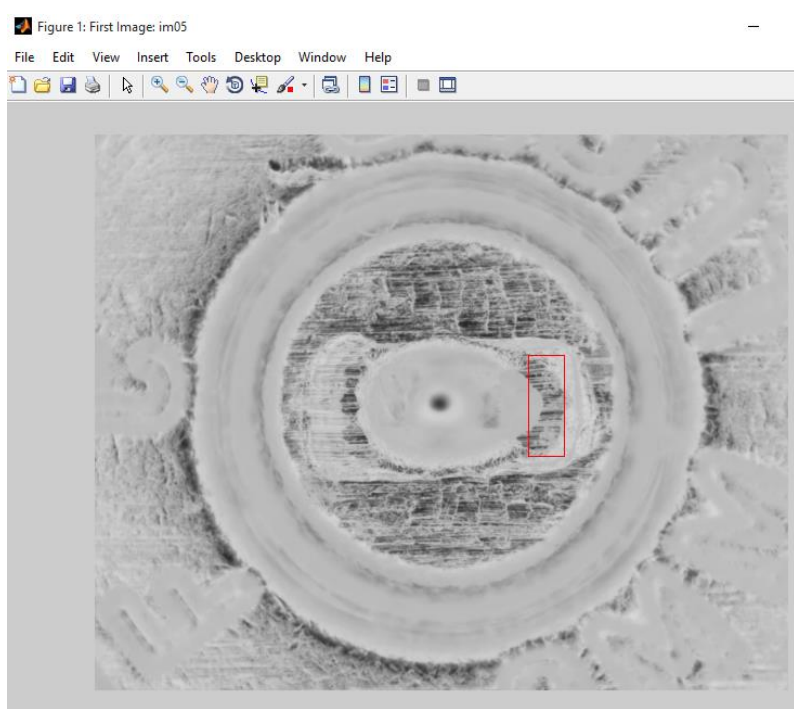
Initial Approach: Implementation



Need to determine an optimal threshold

Or remain continuous

Second Approach: Conceptual



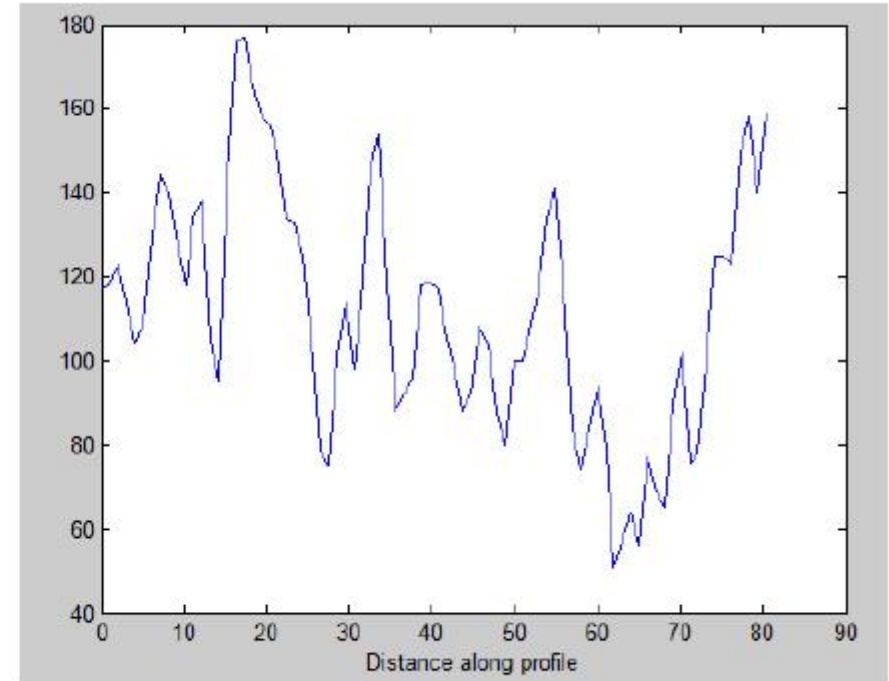
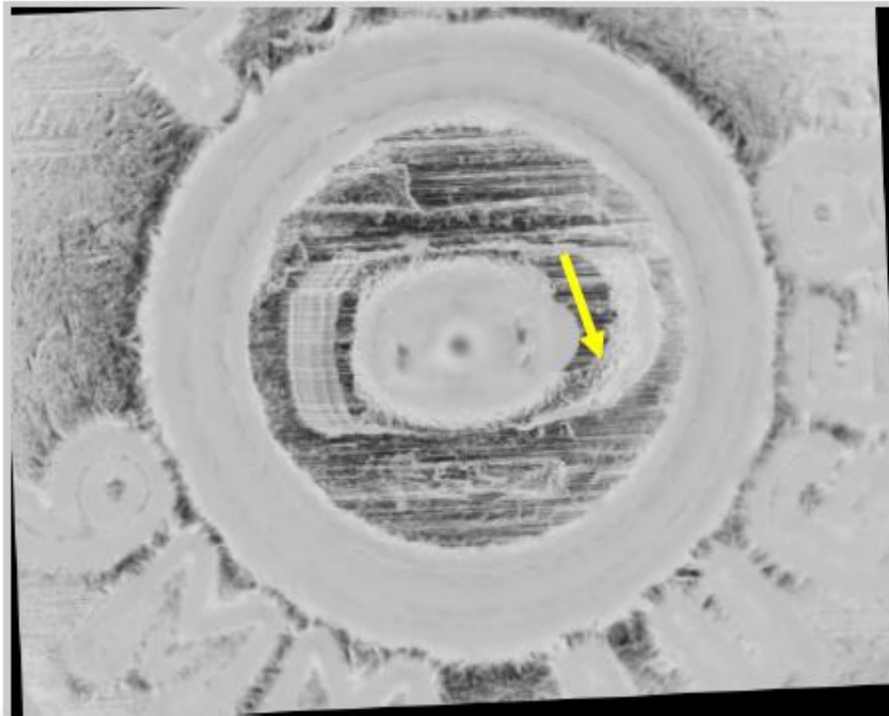
For each infrared image of the cartridge casing, allow the *practitioner* to select the relevant regions of interest.

Appropriately align and smooth these regions, and convert the question of:

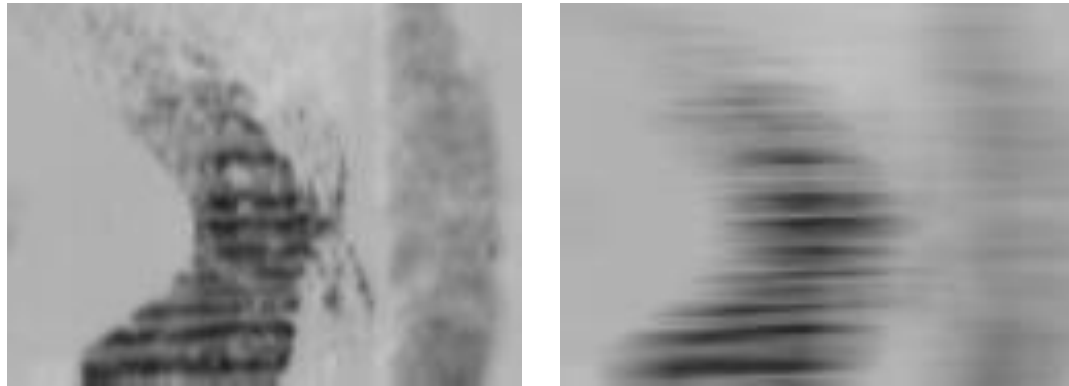
- 1) How similar are these images; to
- 2) How “far apart” are randomly selected slices on these images from each other?

Example Program

Visualizing the pixel intensity



Second Approach: Distance

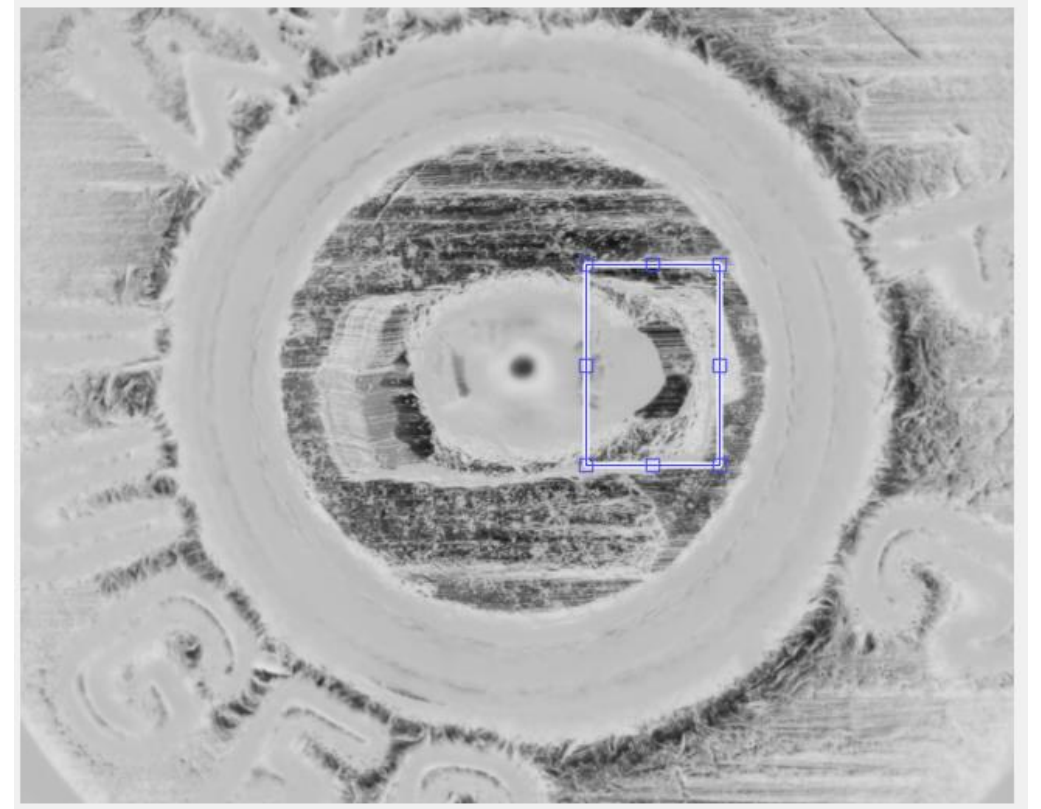
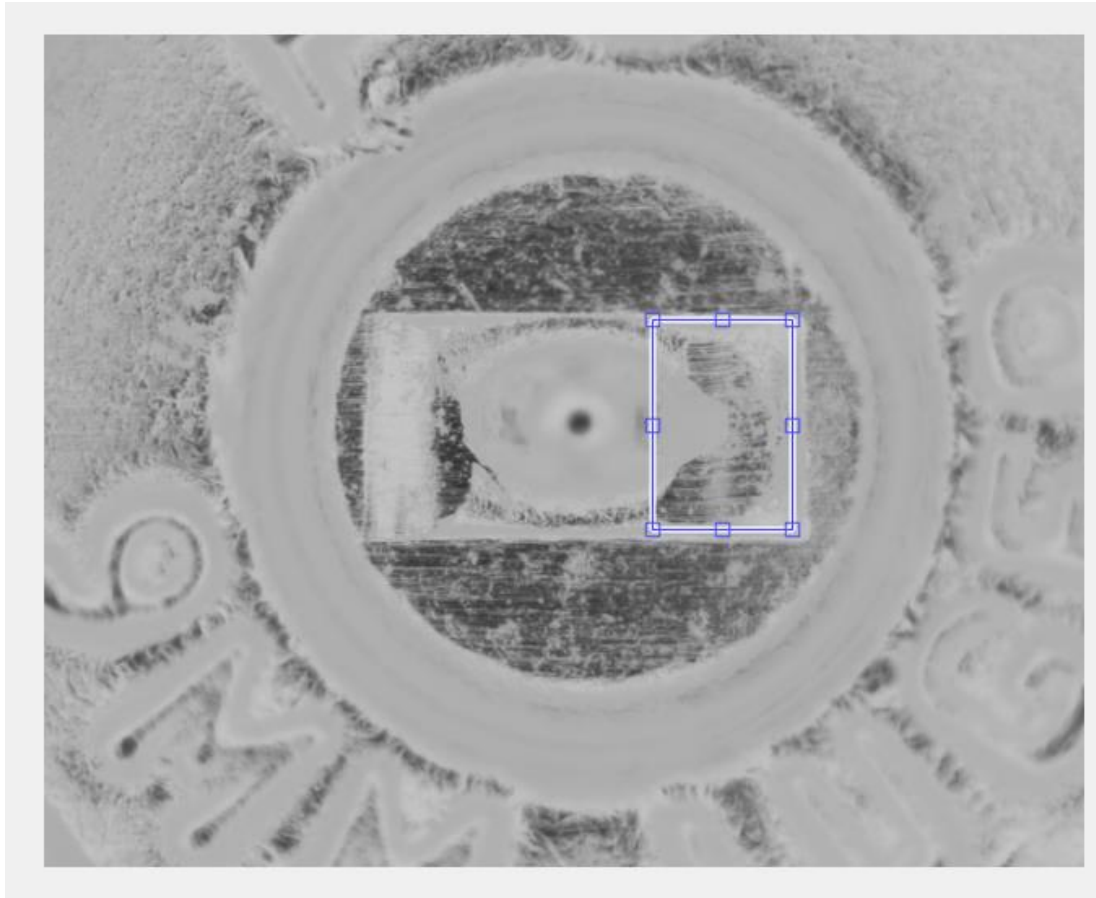


Symmetric Kullback-Leibler divergence using local averaging and requiring non-zero entries.

$$\text{symmetric KL} = \frac{1}{2} \sum_i (p_i - q_i) \ln \left(\frac{p_i}{q_i} \right)$$

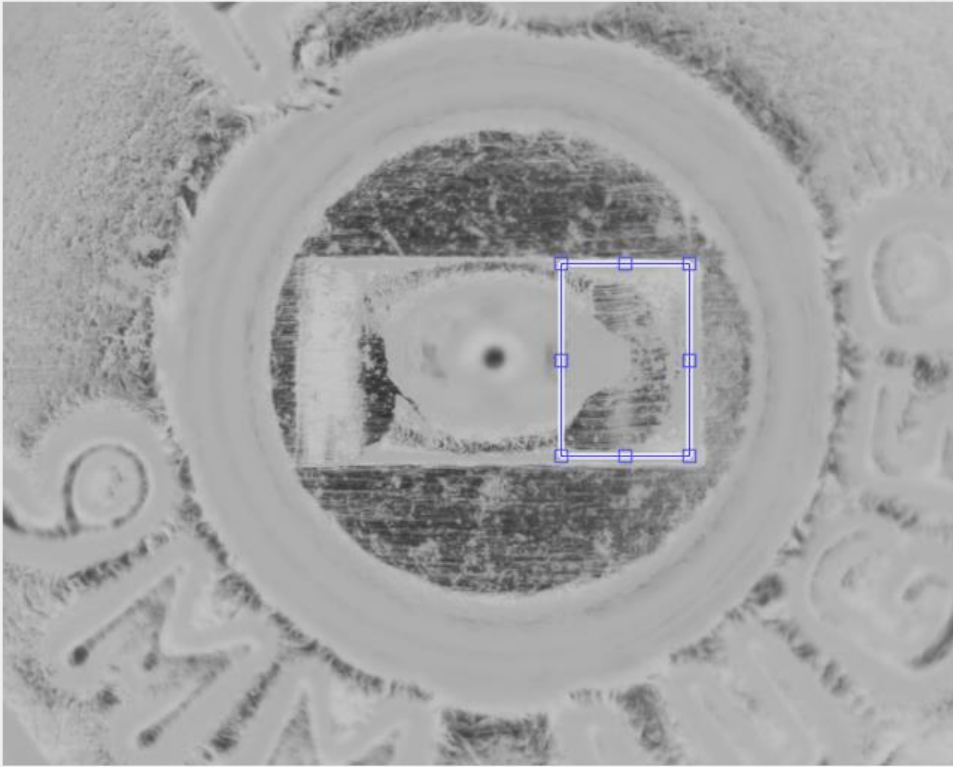
$$\text{local averaging } p_i = \frac{1}{3} \sum_{j=i-1}^{i+1} x_j \quad \text{for } 2 \leq j \leq n-1$$

Example Program



Example Program

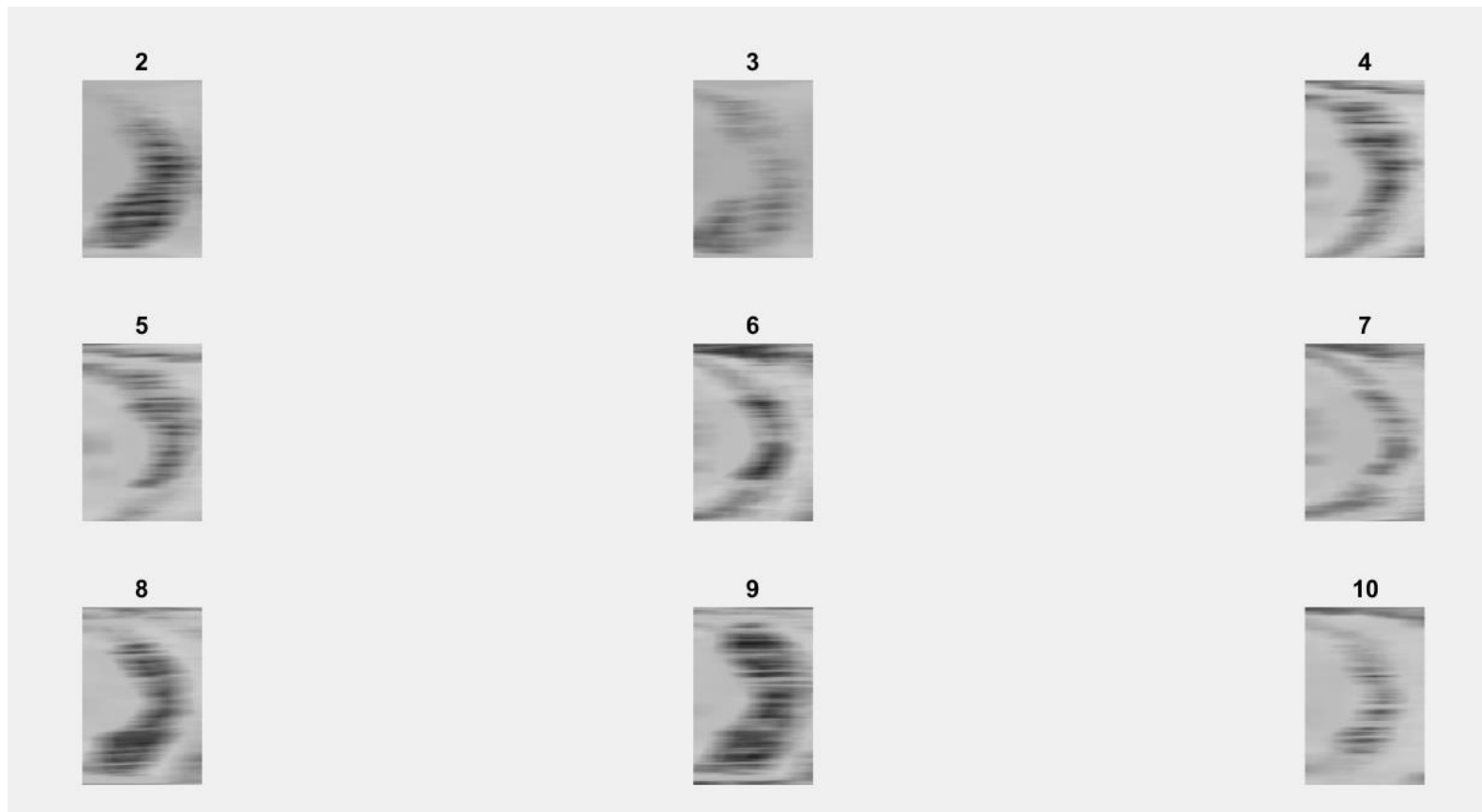
Storing the regions of interest



```
regions =  
  
375  182  86  129  1  
375  176  86  129  2  
366  177  86  129  3  
367  161  86  129  4  
365  166  86  129  5  
378  174  86  129  6  
372  179  86  129  7  
375  181  86  129  8  
358  182  86  129  9  
362  181  86  129  10
```

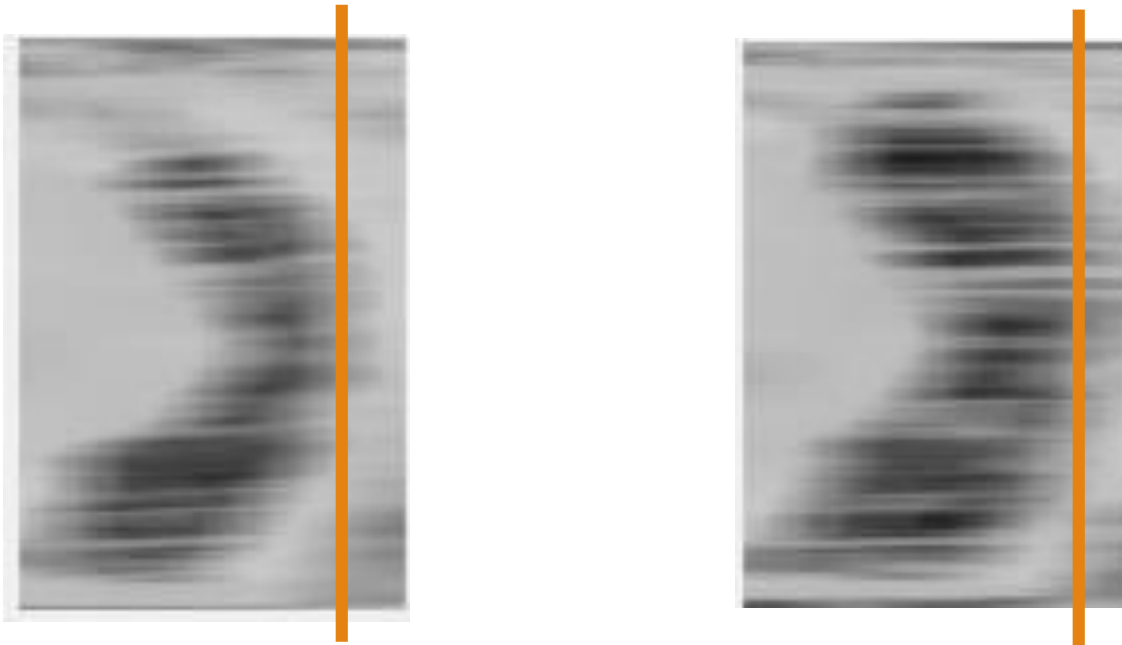

Example Program

Horizontal smoothing of striations



Example Program

Comparing the **same** slice within each pair of images



```
>> region_view( images, regions, 1, 10);  
>> [A] = region_compare( images, regions, 80 , 1 , 3 );  
Evaluating 45 pairs, each with 80 slices, and a bandwidth of 3  
44 43 42 41 40 39 38 37 36 35 34 33
```

Example Program

Comparing **different** slices within each pair of images



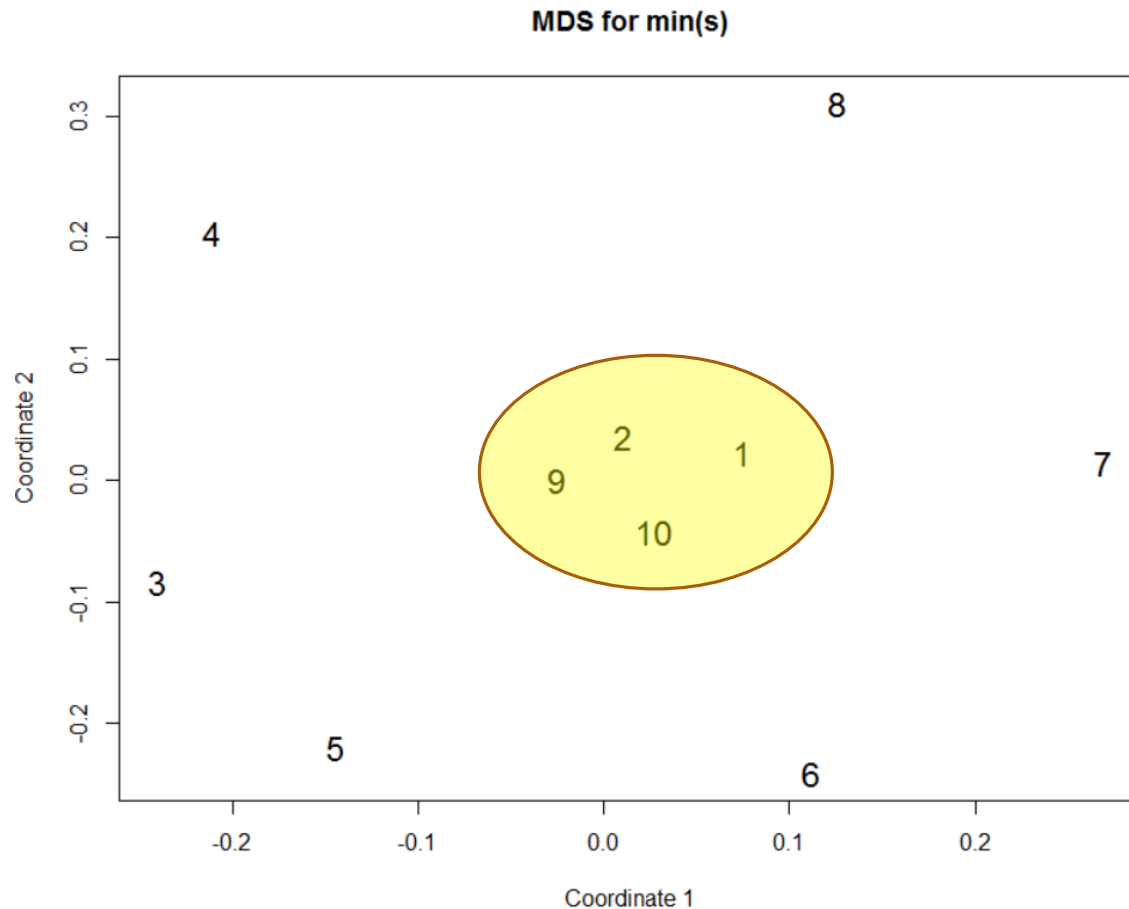
```
>> region_view( images, regions, 1, 10);  
>> [A]      = region_compare( images, regions, 80 , 1 , 3 );  
Evaluating 45 pairs, each with 80 slices, and a bandwidth of 3  
44 43 42 41 40 39 38 37 36 35 34 33
```

Example Program: Results

Example: "Distance" between image pairs							
Pairs of Images		Same Slice			Different Slice		
Image A	Image B	Mean	Mean Variance	Minimum	Mean	Mean Variance	Minimum
1	2	2.81	0.10	0.01	4.52	0.24	0.06
1	3	2.60	0.05	0.13	4.14	0.13	0.26
1	4	2.51	0.06	0.13	4.50	0.17	0.22
2	3	2.31	0.02	0.12	3.02	0.07	0.37
2	4	1.59	0.02	0.19	2.41	0.04	0.14
3	4	1.51	0.01	0.21	3.22	0.05	0.24

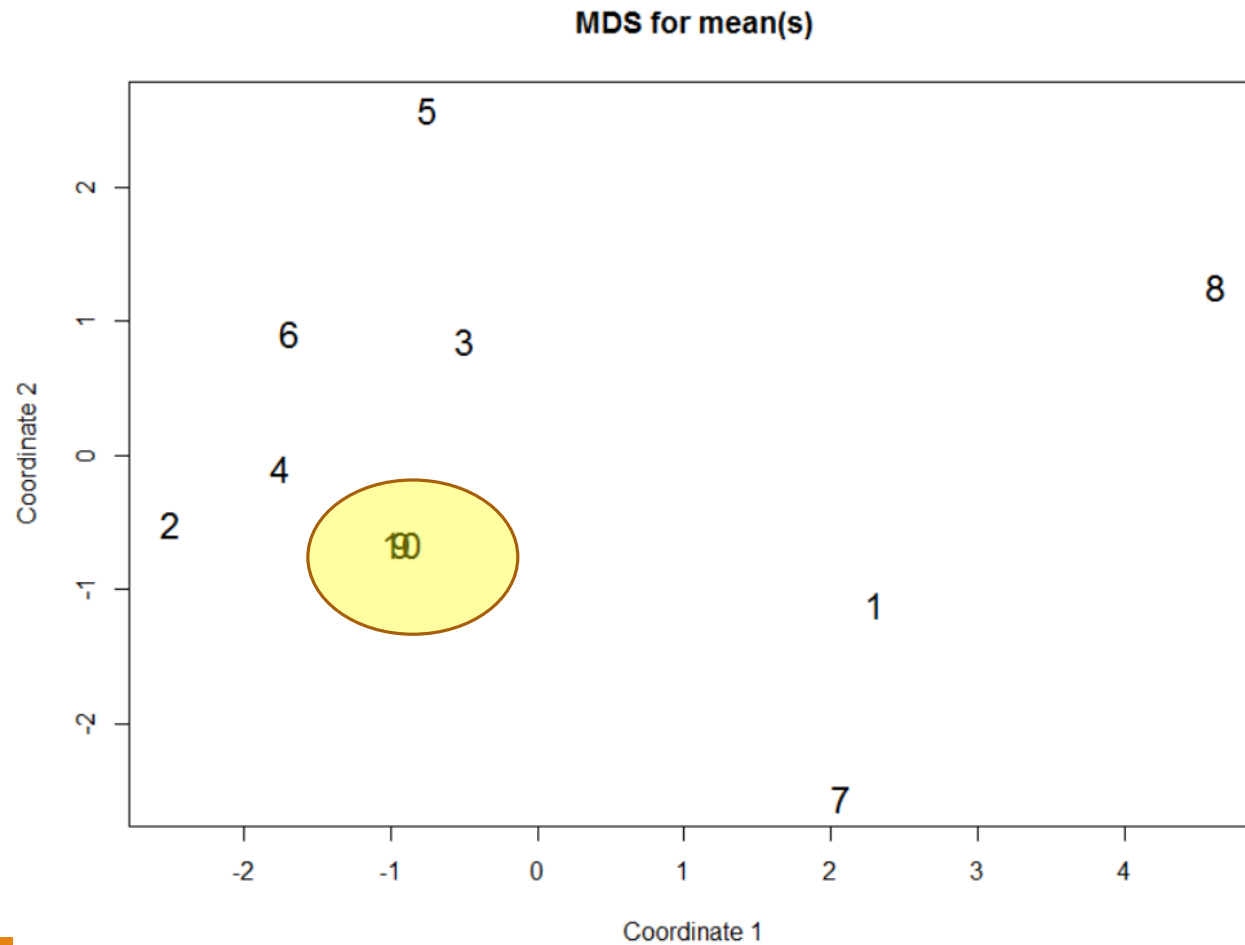
All summary statistics are multiplied by 100

Example Program: Visualization



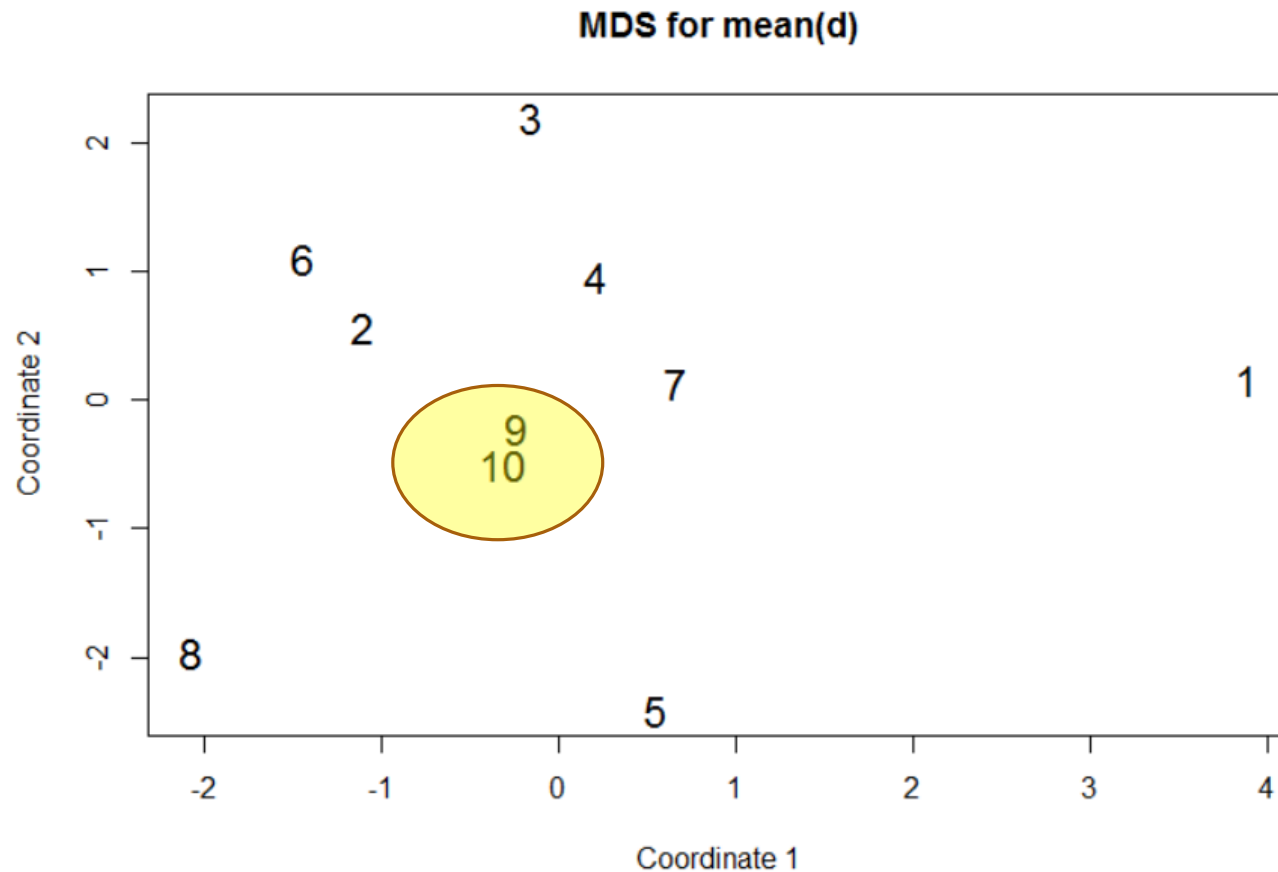
Using multidimensional scaling
(R function: isoMDS in MASS)

Example Program: Visualization



Using multidimensional scaling
(R function: isoMDS in MASS)

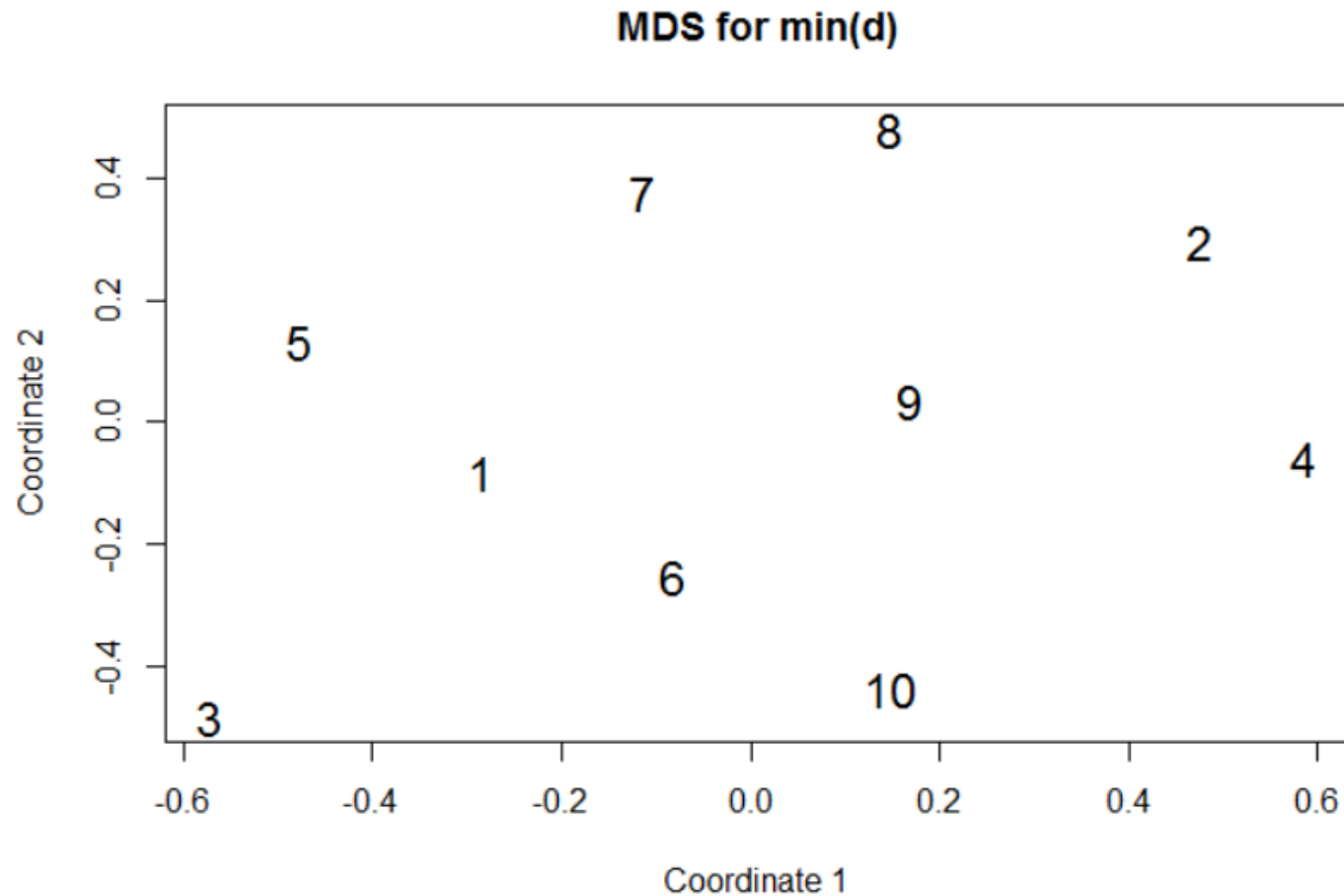
Example Program: Visualization



Examining different slices
on larger regions

Using multidimensional scaling
(R function: `isoMDS` in MASS)

Example Program: Visualization



Examining different slices
on larger regions

Using multidimensional scaling
(R function: isoMDS in MASS)

Limitations and Future Research

Rotation and Alignment Issues

Sensitivity to Region Specified

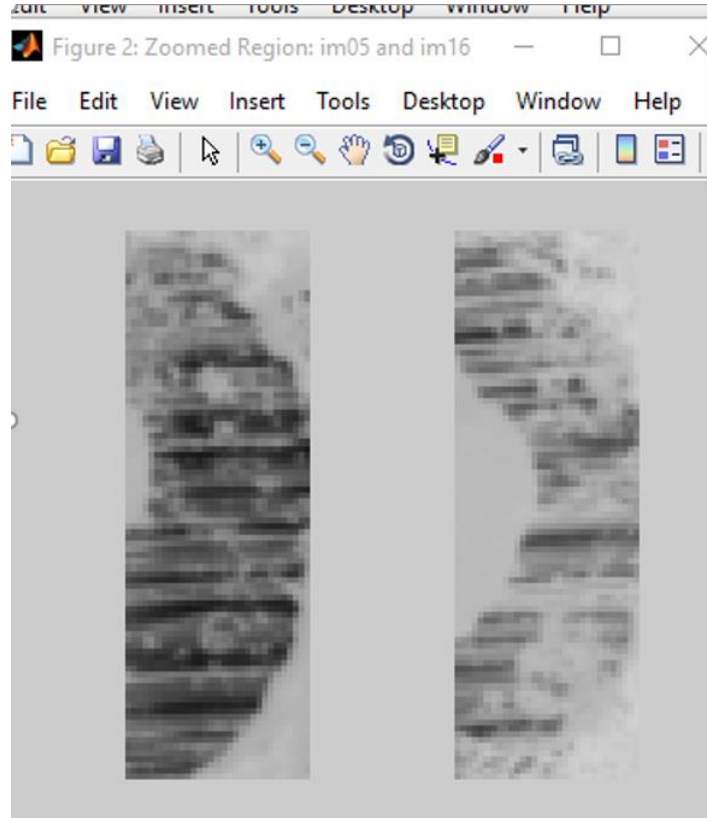
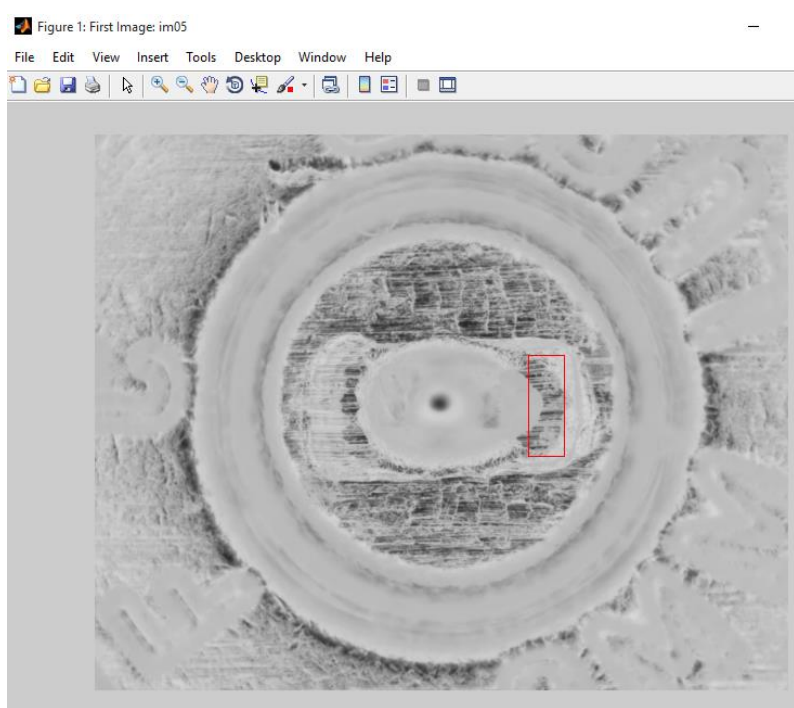
Small Sample Size

Desire for more images of cartridges fired by multiple types of brands/weapons/models

Incorporating uncertainty in the analysis

Deep learning approach?

Recap



For each infrared image of the cartridge casing, allow the *practitioner* to select the relevant regions of interest.

Appropriately align and smooth these regions, and convert the question of:

- 1) How similar are these images; to
- 2) How “far apart” are randomly selected slices on these images from each other?

Acknowledgements

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