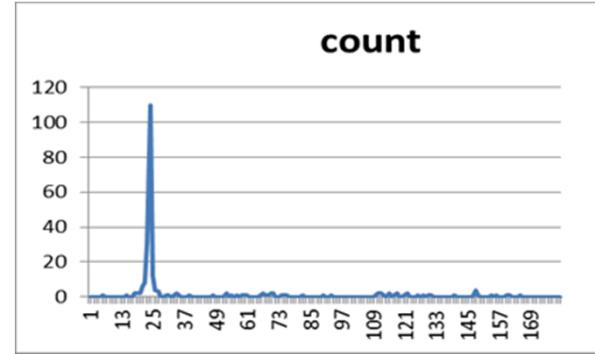
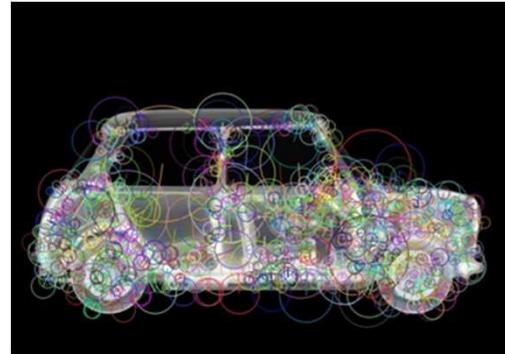
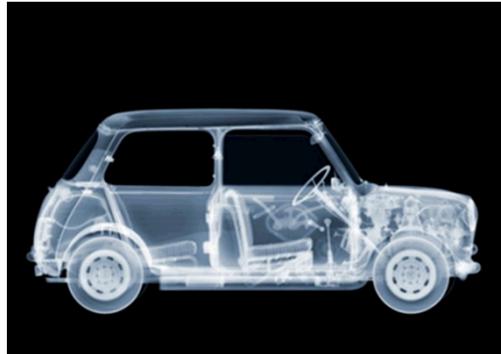


*Exceptional service in the national interest*



# SURF Feature Matching Applied to Radiography

Charles Little, Chris Wilson

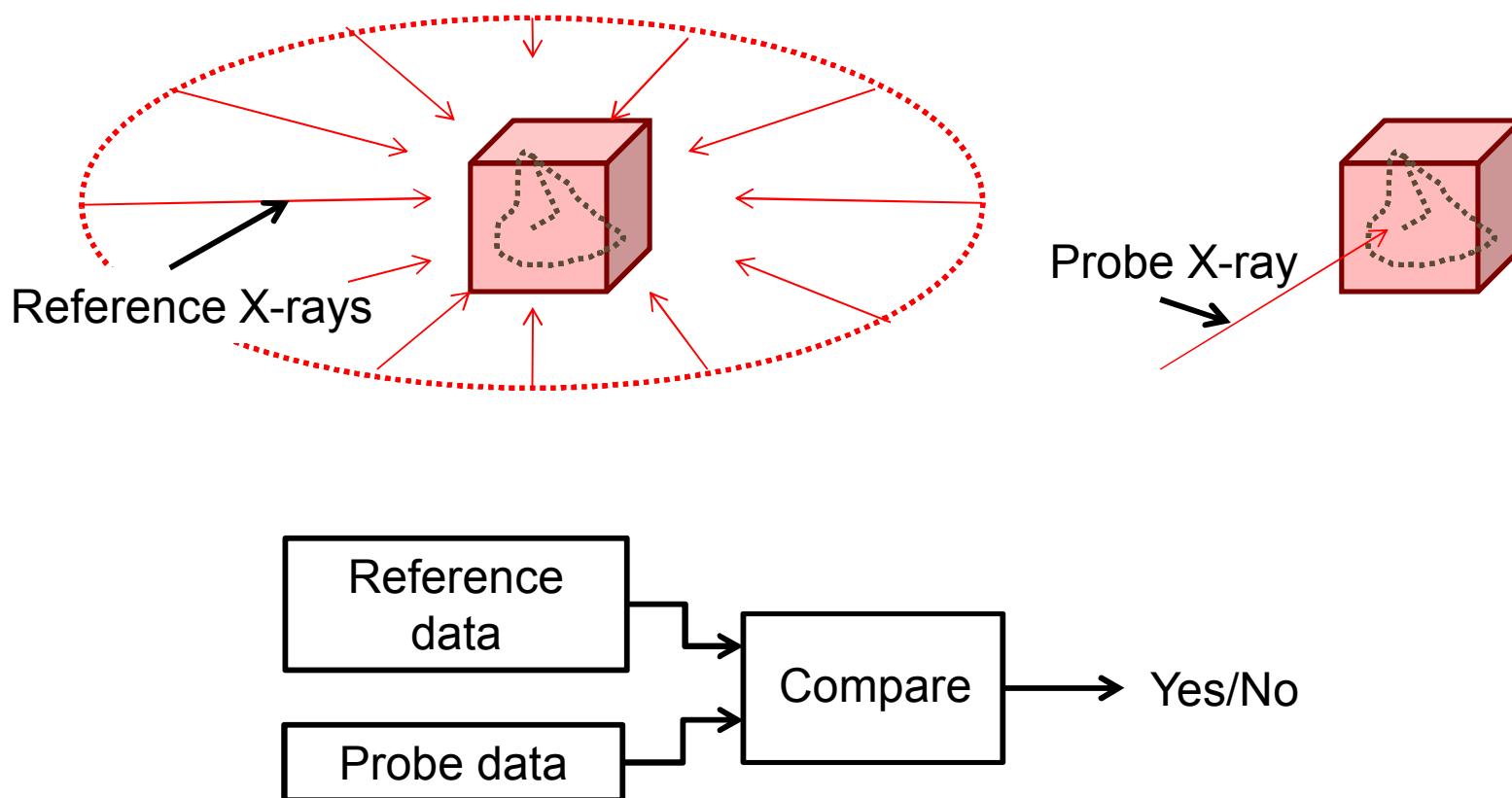
**Workshop on Techniques for Protection of Imaging Information 06/01/2016**



Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND NO. 2015-5443 C

# Image Matching

- Goal – find a target image in a set of reference images

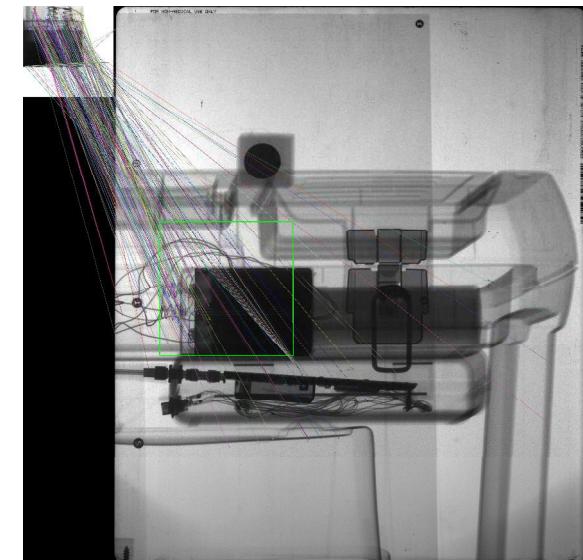
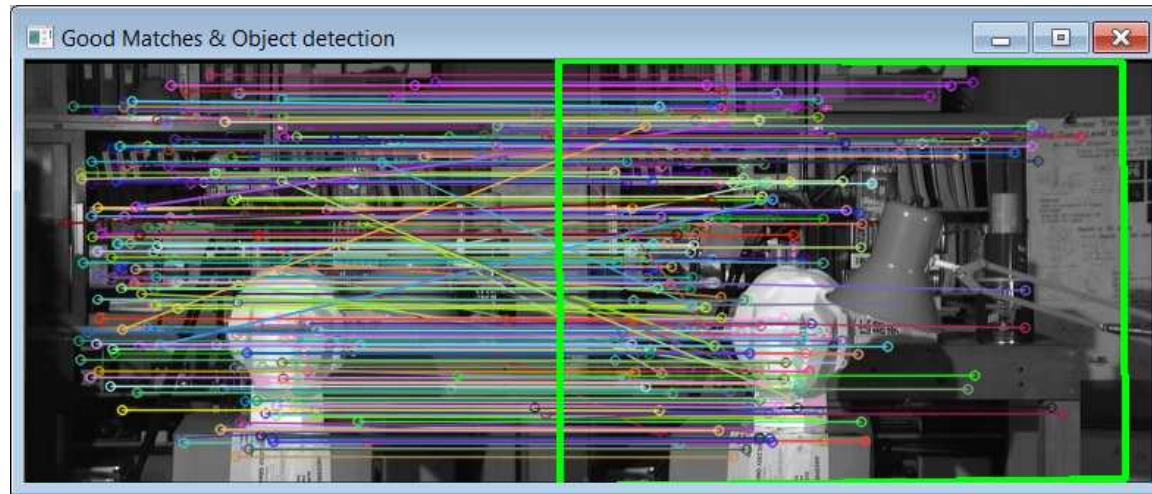


# Image Matching -- Feature based matching

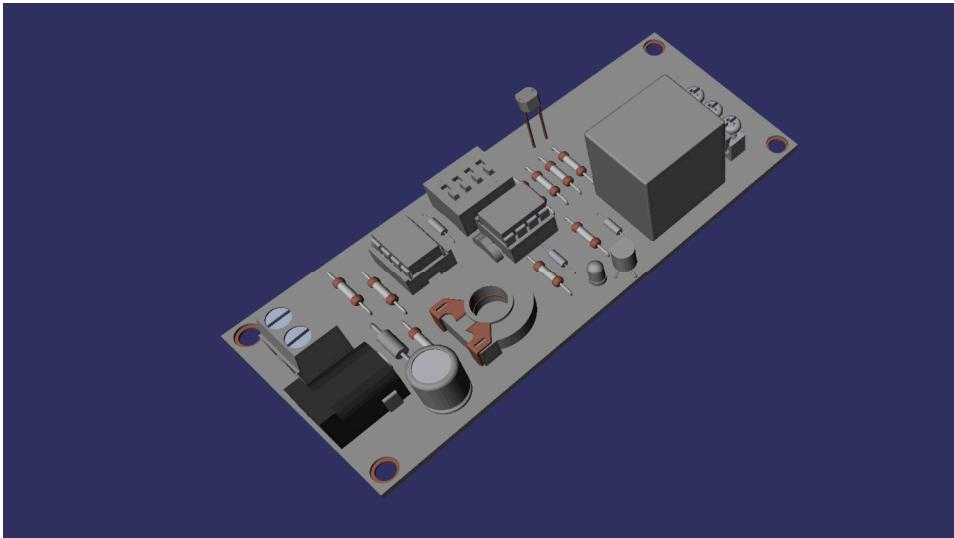
Match a target image to a reference image



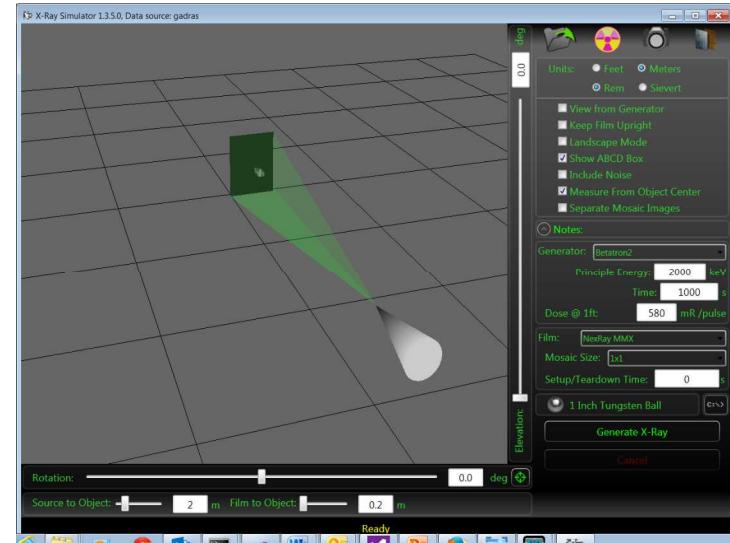
Can be scale and  
rotation invariant



# Radiography of CAD Models

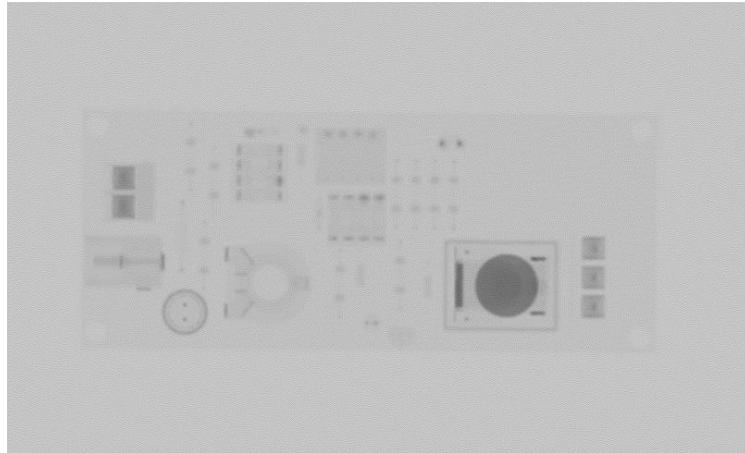
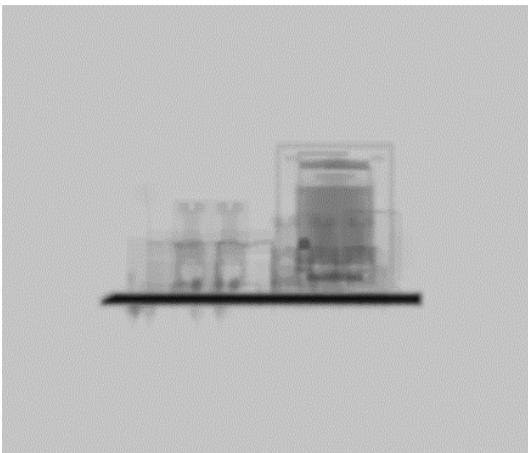


CAD Model of timing circuit



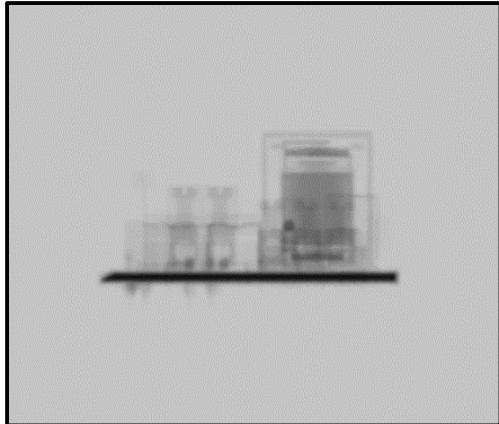
X-ray simulator

X-ray  
images

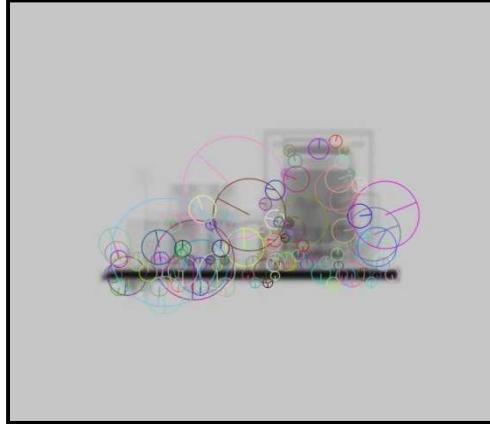


# Image Matching -- Feature based matching

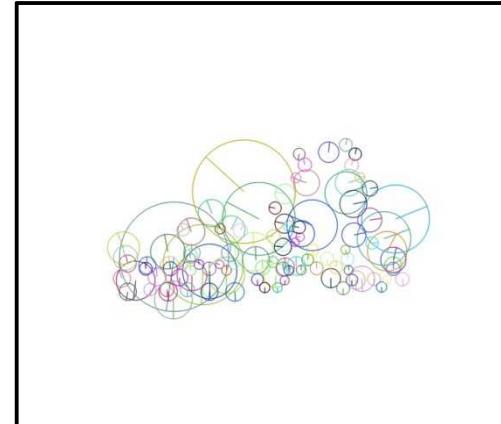
## SURF based feature extraction



X-Ray

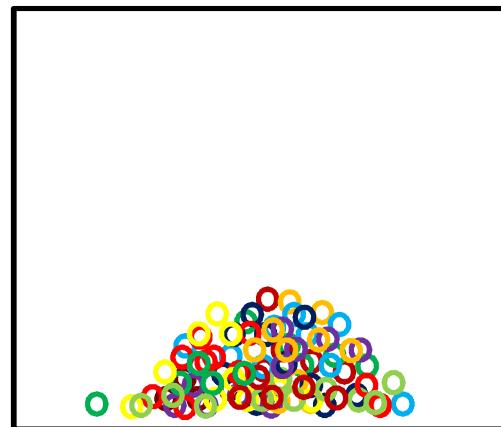


X-Ray with features



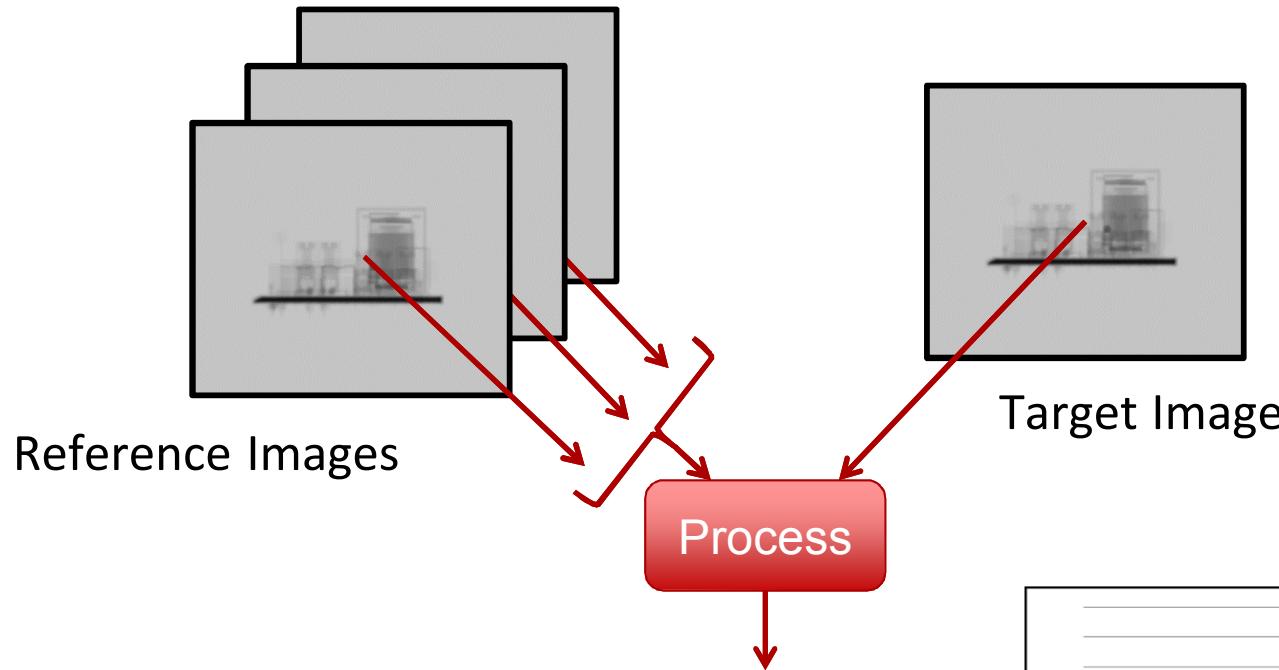
Features only

Features without  
geometry

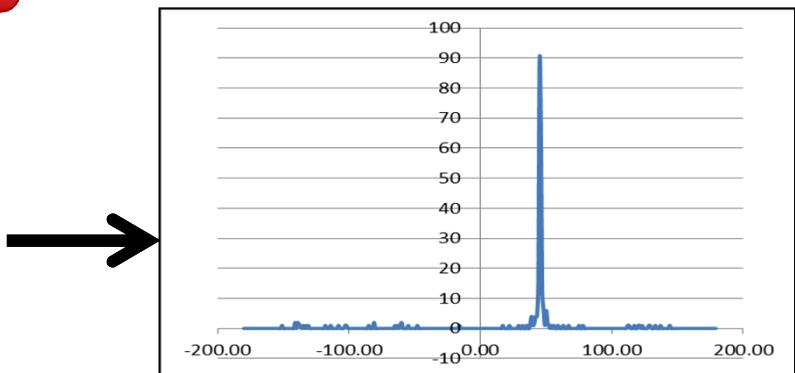


# Image Matching -- Feature based matching

## One-to-Many Matching

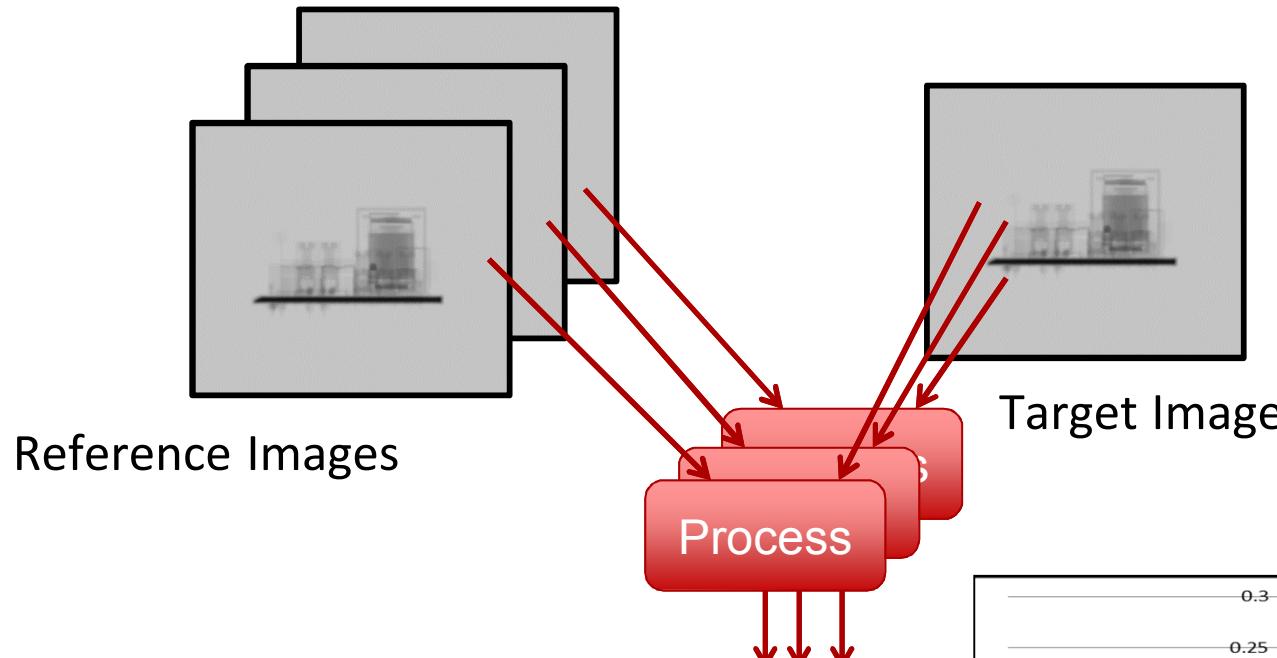


All reference image features collectively matched with the target image. Match value determined by which ref image has the most features that match the target

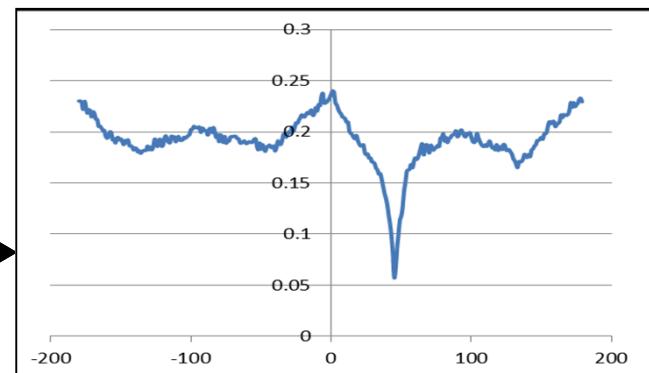


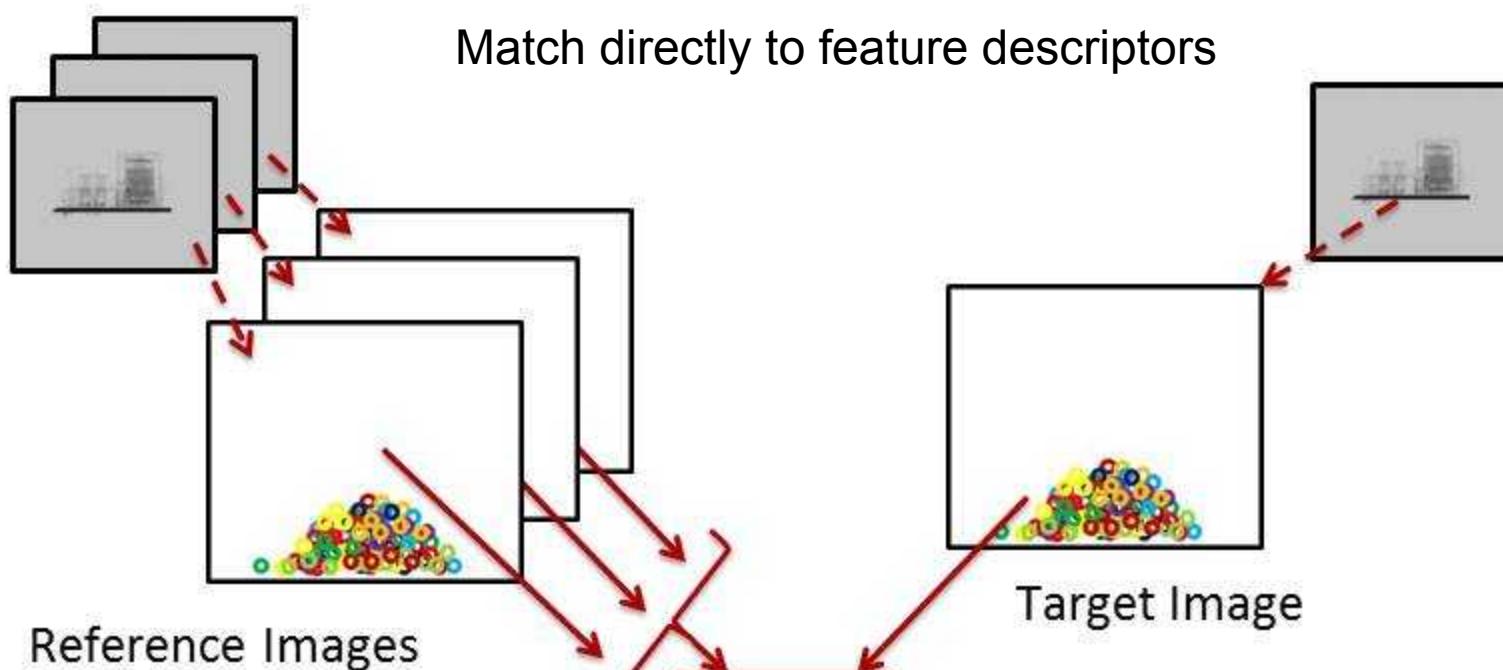
# Image Matching -- Feature based matching

## One-to-One Matching

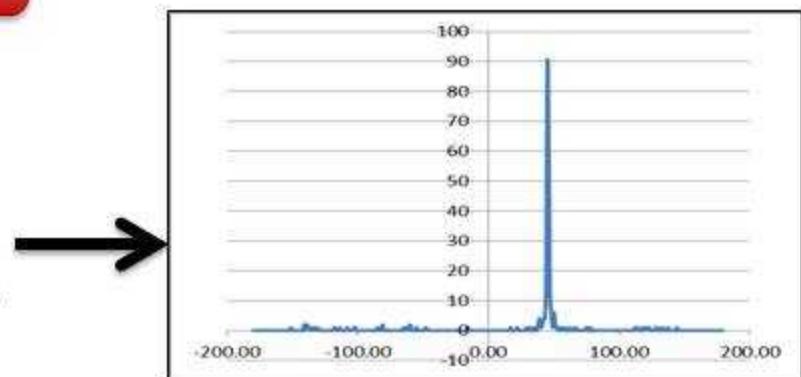


Each reference image is matched separately with the target image.  
Match value determined by aggregate distance measurement.





All reference image features collectively matched with the target image. Match value determined by which ref image has the most features that match the target



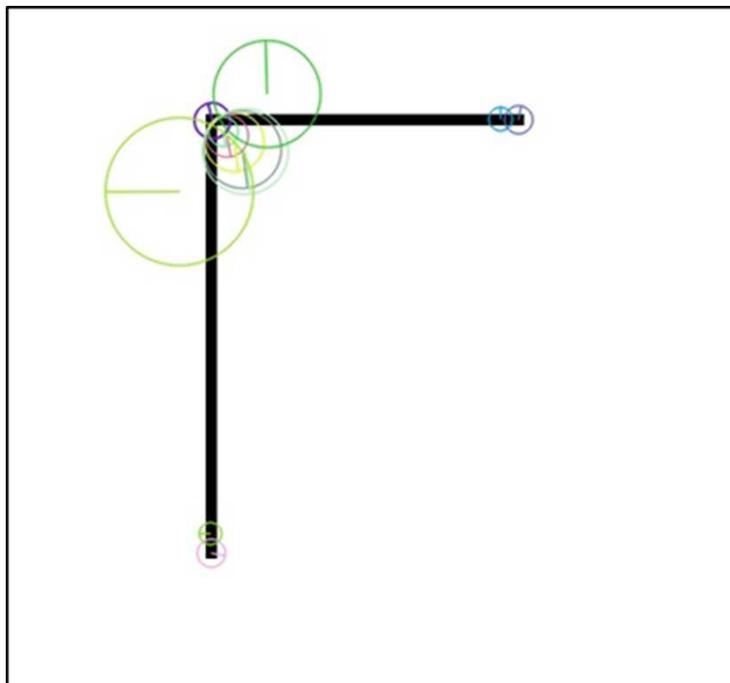
# Irreversibility

## What does irreversibility mean?

1. The feature extraction algorithm is not directly (mathematically) invertible
2. If an image was created using features from representative images, the quality is insufficient for extracting any sensitive device characteristics.
3. The computation time required to recreate an interpretable image is insurmountable and nearly impossible on human time scale

# Irreversibility

## SURF (Speeded Up Robust Features)



### Keypoints

- location, scale, orientation,...(7)

### Keypoint descriptors

- array of numerical values (128)

# Irreversibility

## To recreate an image from feature data

(can't use original image patches, Daneshi and Guo )

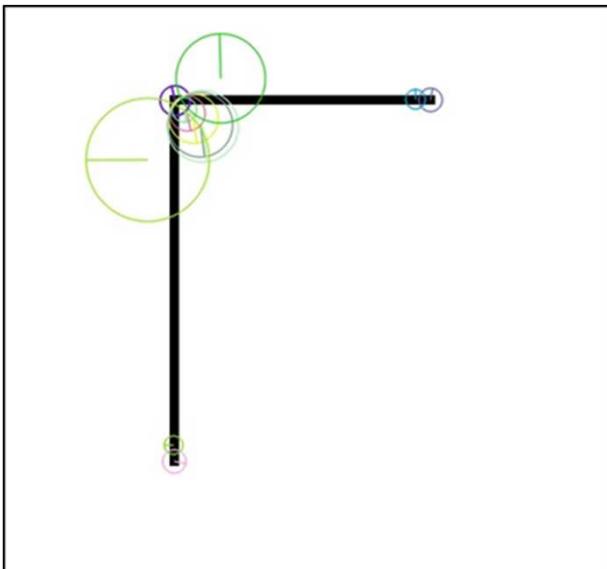
1. For each descriptor find a matching descriptor in a database of representative images and extract corresponding image patch
2. Place patch in the recreated image and scale accordingly to scale in descriptor
3. Repeat for all descriptors
4. Interpolate and combine patches to form image



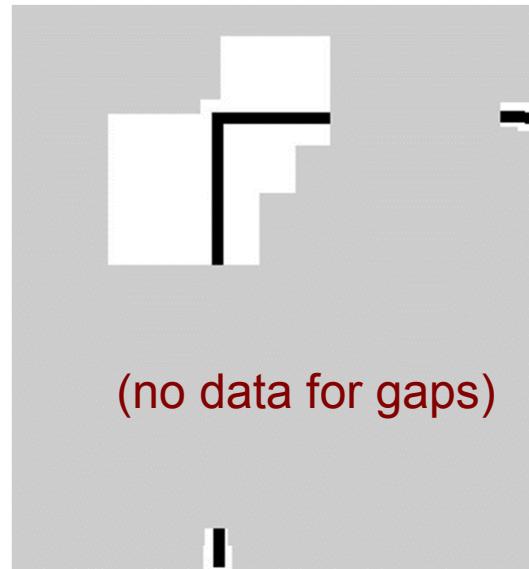
# Irreversibility

If we found representative patches;

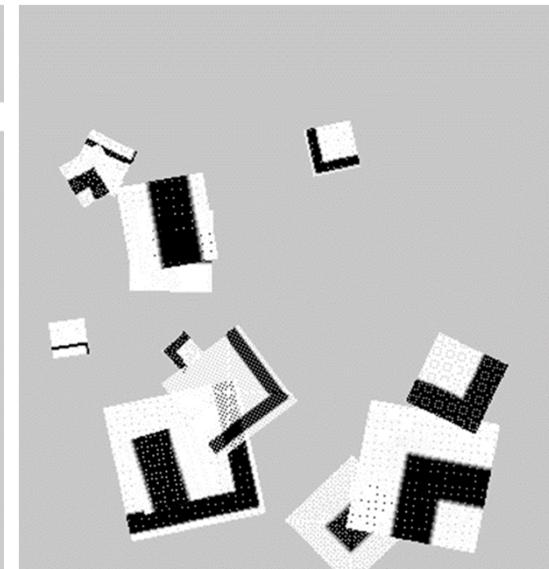
(Original)



With location, scale,  
orientation



Without location, scale,  
orientation



# Irreversibility

## Probability of successfully reconstructing image

If each feature was centered on a given pixel within the to-be-created image, there are  $L$  pixel locations (rows x columns), and  $L!$  combinations of pixel locations. Given  $M$  features, the number of possible arrangements  $N$  would be:

$$N = \frac{L!}{(L - M)!}$$

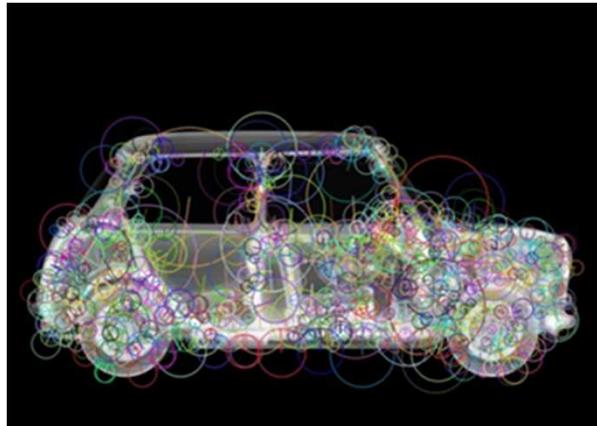
For an image of 100 pixels (10 by 10), with 20 features,  $N$  would be  $1.30 \times 10^{39}$ .

To calculate the expected time to a success, we use

$$T_{success} = \frac{pN}{2r}$$

where,  $p$  is the probability of success,  $N$  is the number of possible arrangements, and  $r$  is the rate the arrangements can be calculated. For the same 20 descriptors and 100 pixels, we will assume we want a 90% probability of success and the rate will be 5 MHz. It would require a time of  $1.96 \times 10^{30}$  minutes or  $3.7 \times 10^{24}$  years to test all possible arrangements.

# Irreversibility



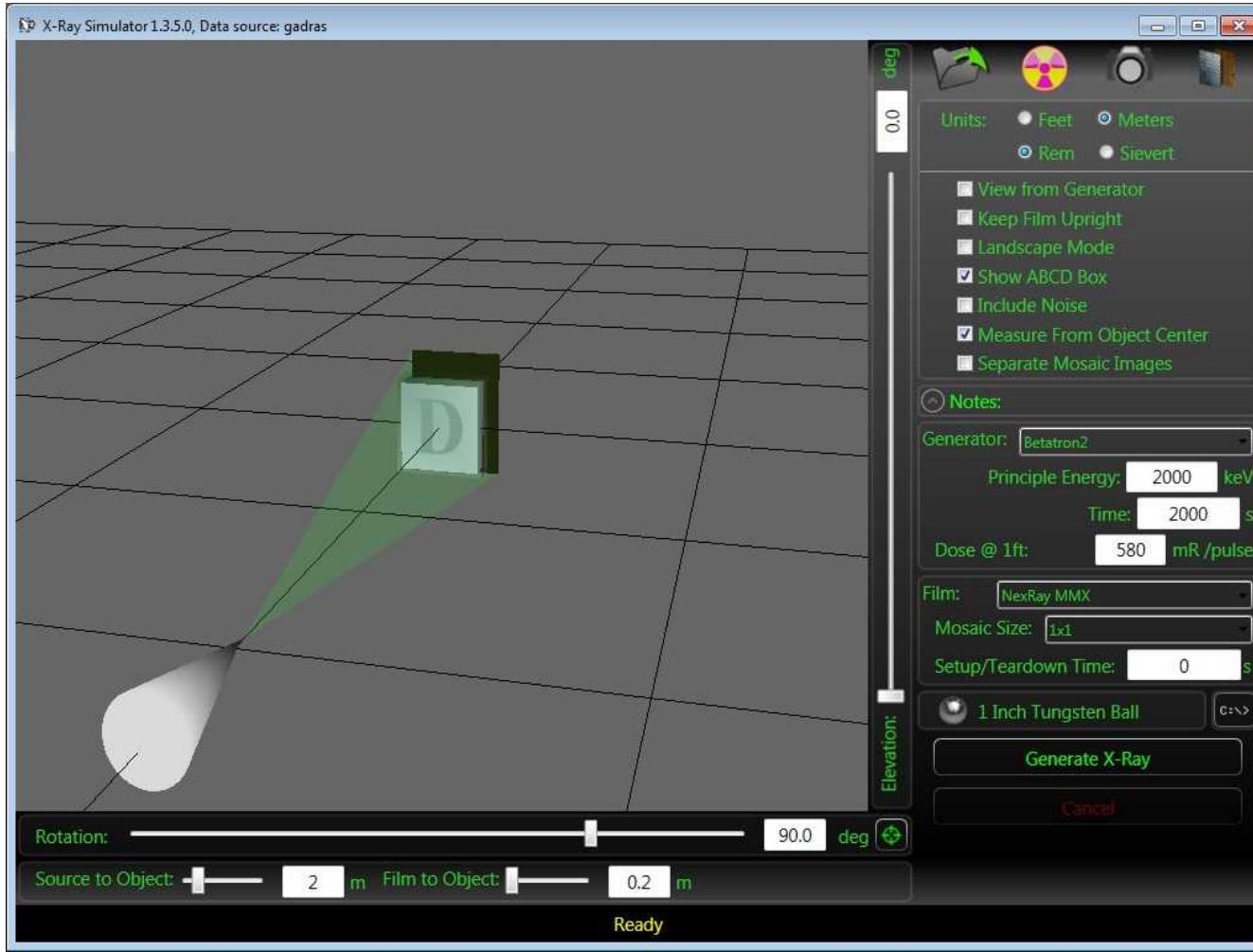
Example radiography image:

Car.jpg  
640 x 452 Pixels  
1201 SURF Features

Unknown Orientation and Scale could be considered multipliers on the Position space when considering possible feature arrangements.

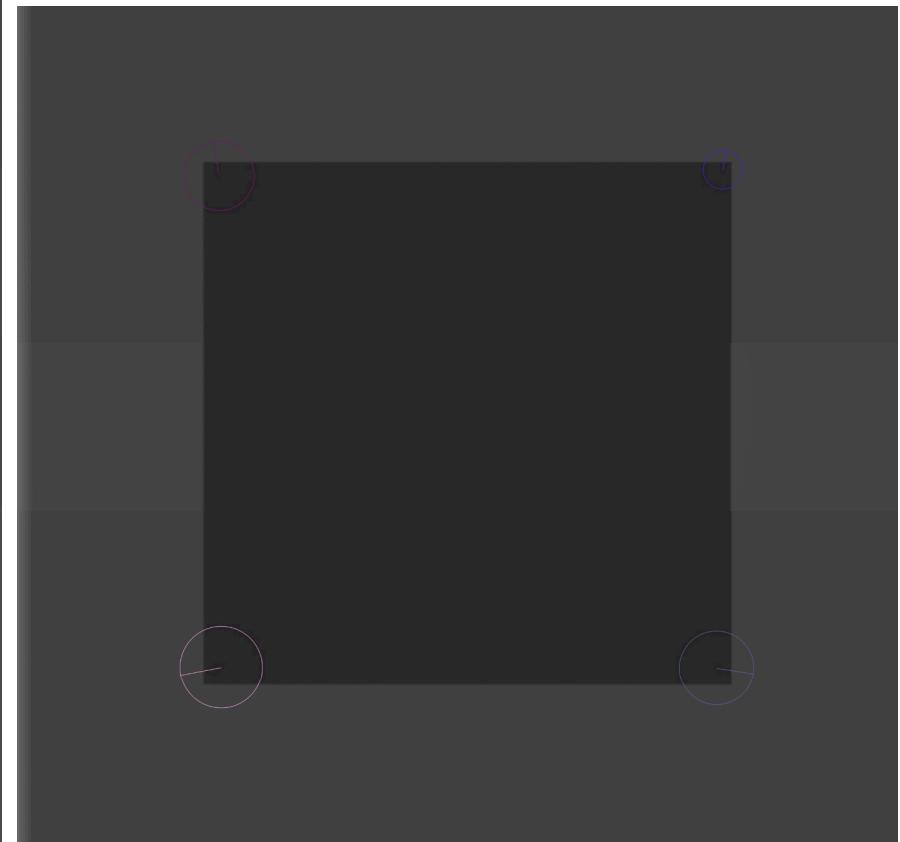
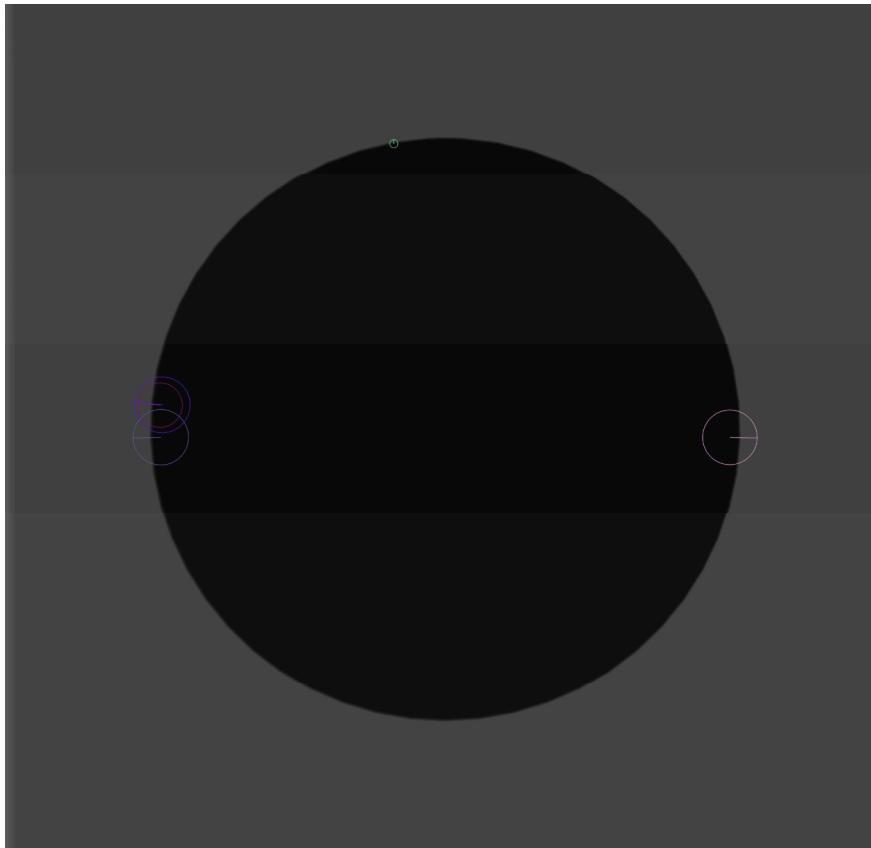
# Challenge Problem

## CAD model for X-ray simulation



# Challenge Problem

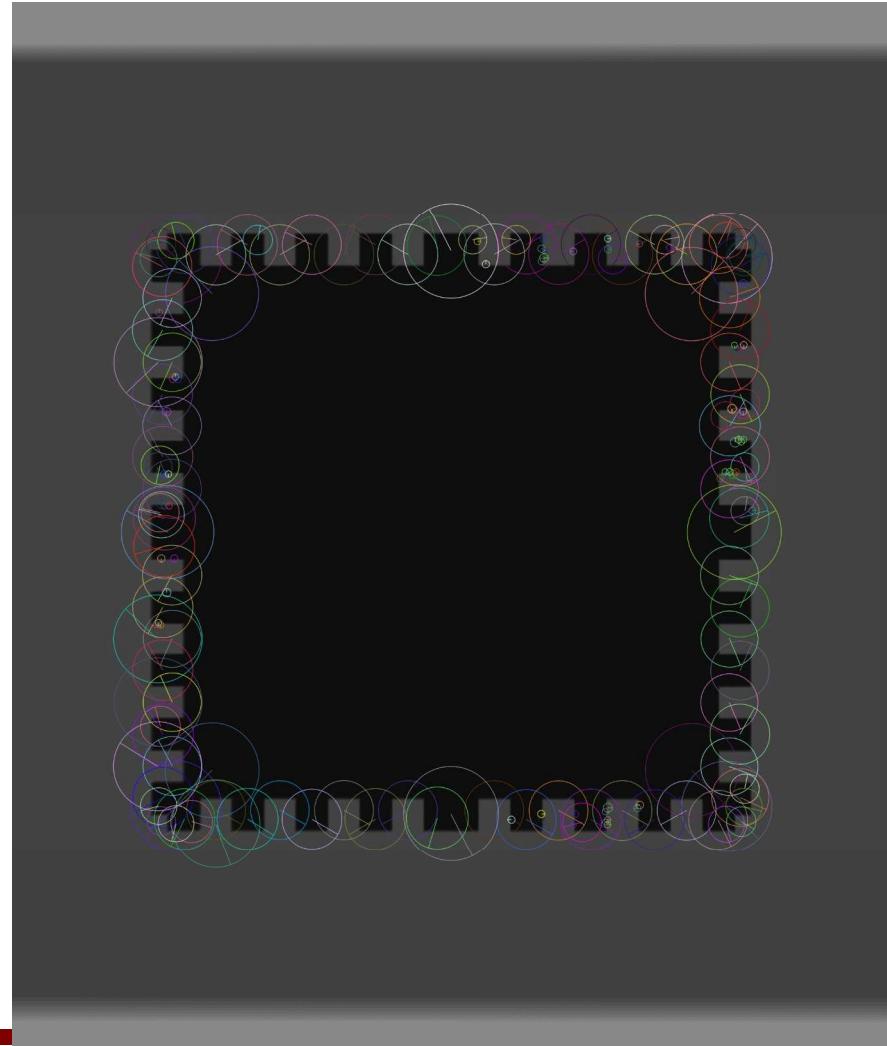
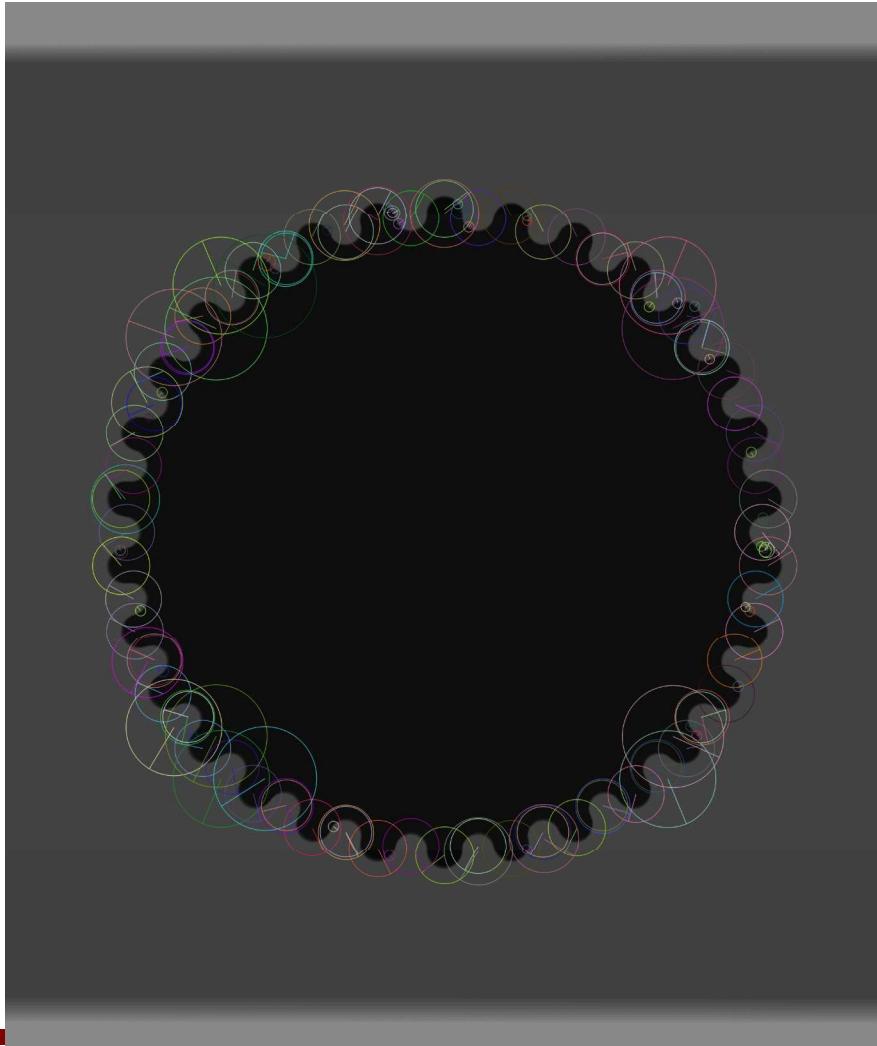
X-rays of original models with features



Too few features for algorithm

# Challenge Problem

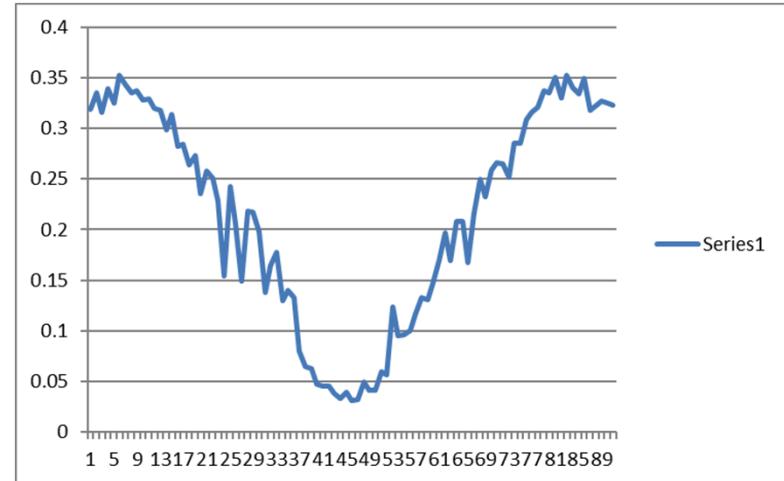
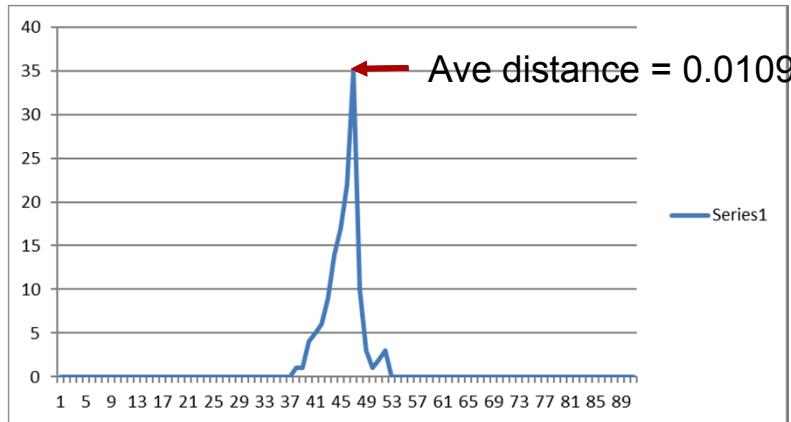
X-rays of modified models with features



# Challenge Problem

## Probe vs Reference set matching

Disk to Disk



Square to Disk

