SAND2016-8481C

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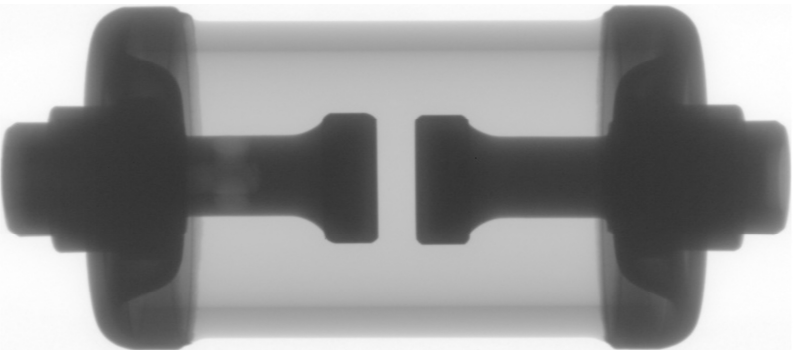
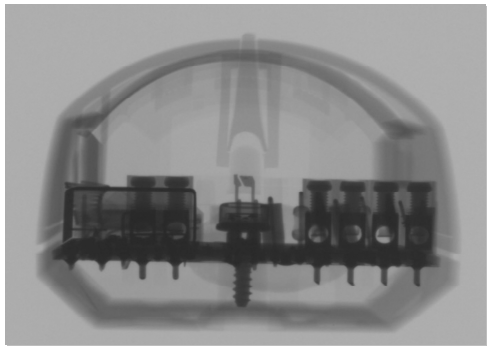
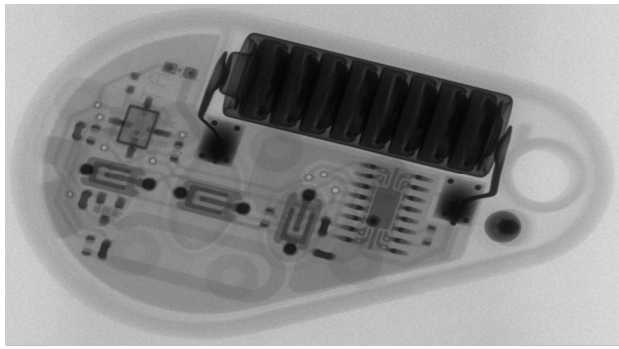

Exploration of Available Feature Detection and Recognition Systems and their Performance on Radiographs

Andrew C. Wantuch, Joshua A. Vita, Edward S. Jimenez, and Iliana E. Bray

Sandia National Laboratories, Software Systems R&D

U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

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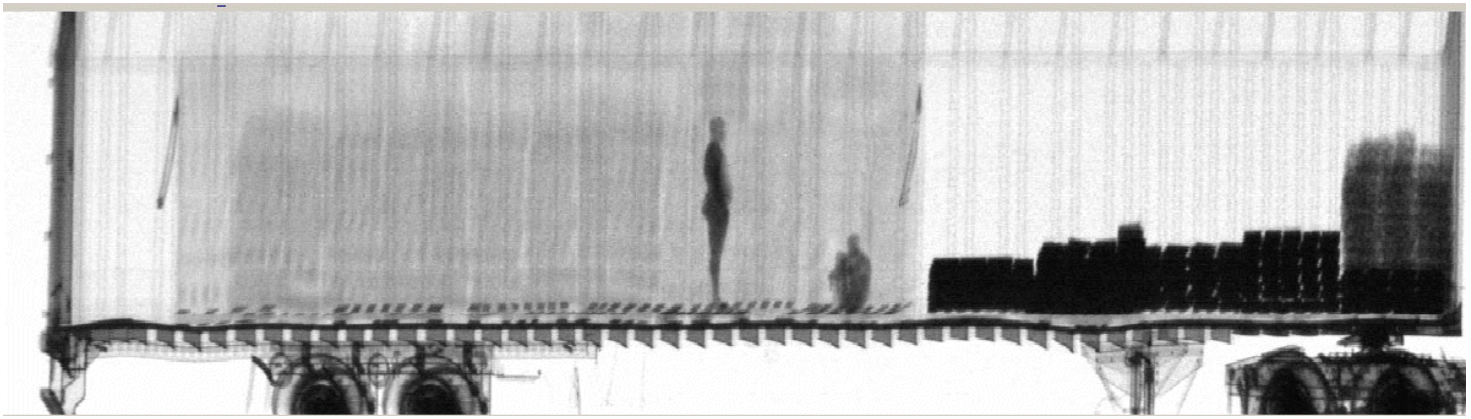
Goal

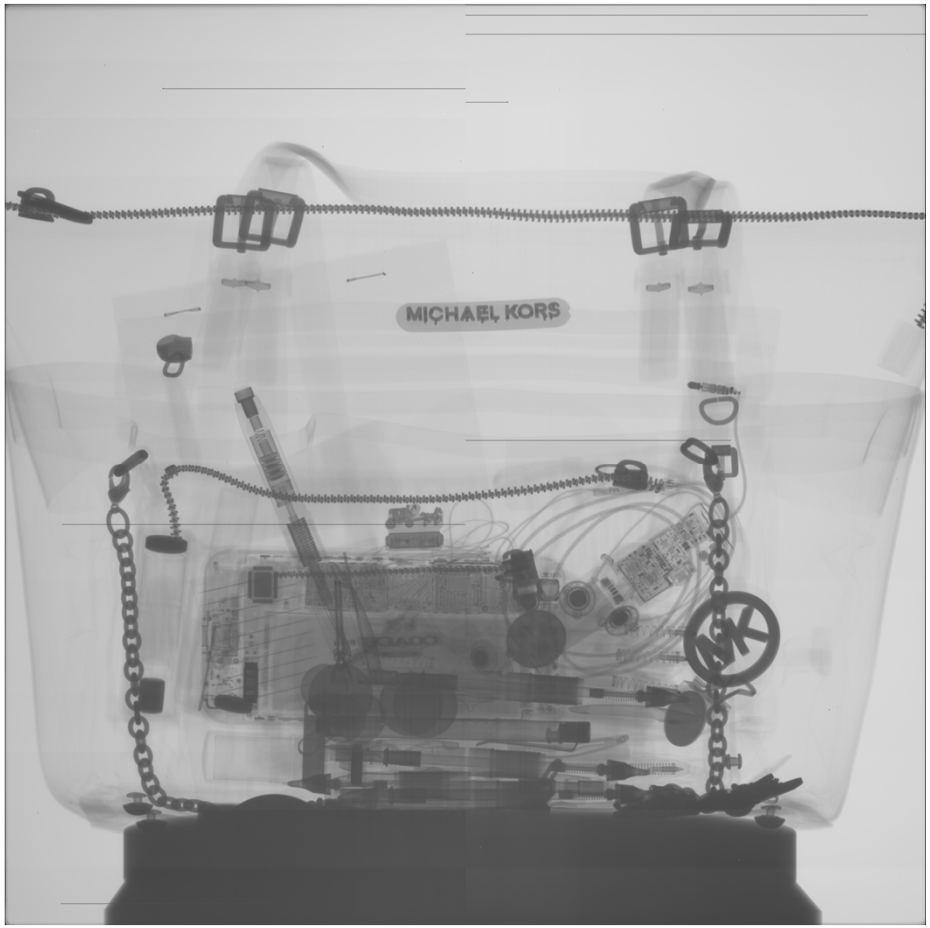
- Image recognition using radiographs captured in the wild.
- Potential applications include:
  - Checkpoint Security
  - Component Recognition
  - Nondestructive Evaluation
  - Reverse Engineering



Source: https://upload.wikimedia.org/wikipedia/commons/d/d7/VACIS_Gamma-ray_Image_with_stowaways.GIF

Challenge - Radiographs

- Object Recognition in X-rays
  - **Occlusion**
  - Perspective
  - Noise



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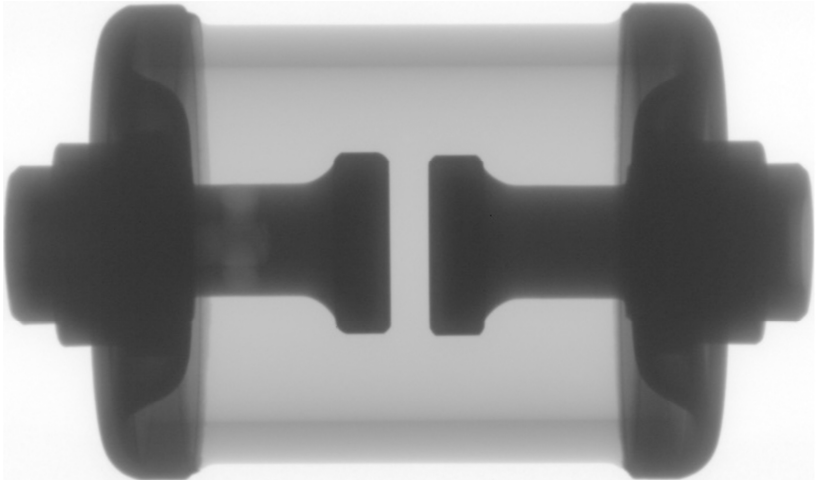

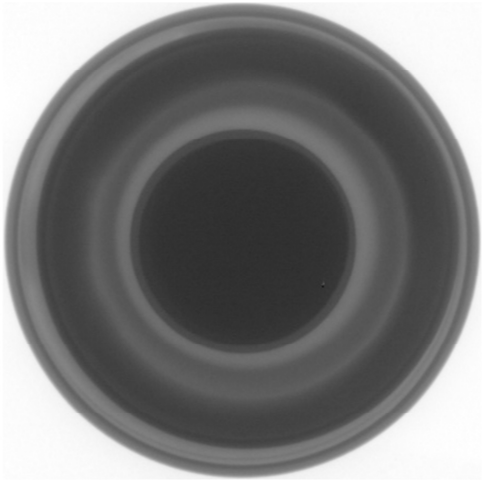

Challenge - Radiographs

- Object Recognition in X-rays
  - Occlusion
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Challenge - Database

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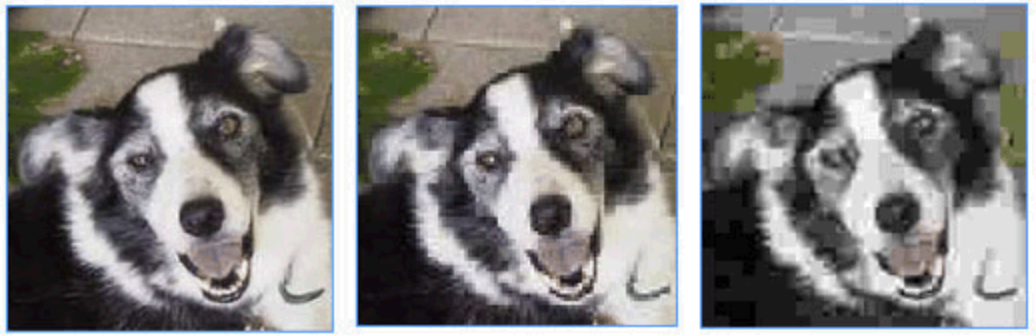
- Database Constraints
  - **JPEG images - lossy compression**
  - Inconsistent/insufficient energy
  - Unclean/modified images
  - Limited/inconsistent views
  - Similar Objects
  - Subcomponents
  - Useless Images



- Image source: http://cdn.mos.cms.futurecdn.net/26db74f7c66961368a34408c33f00f18.jpg

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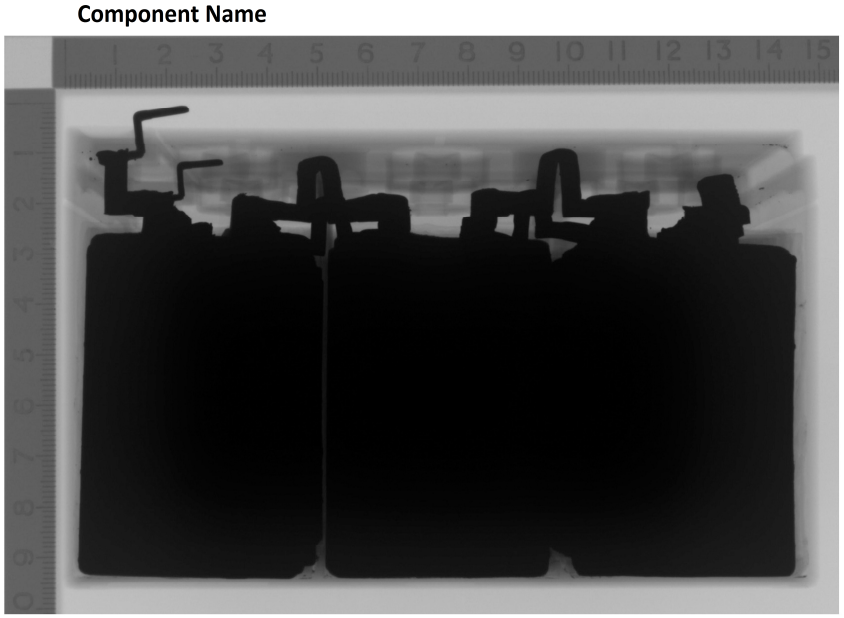

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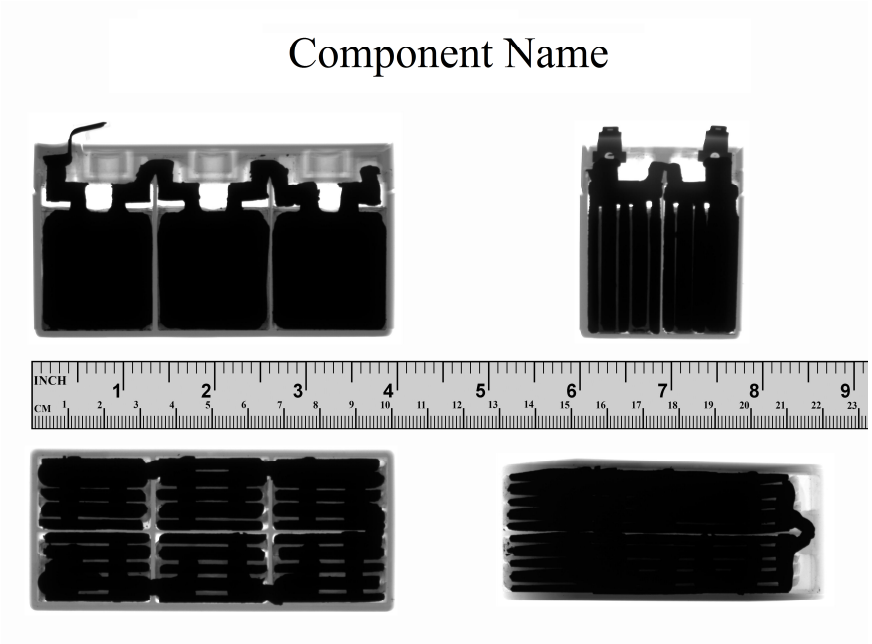

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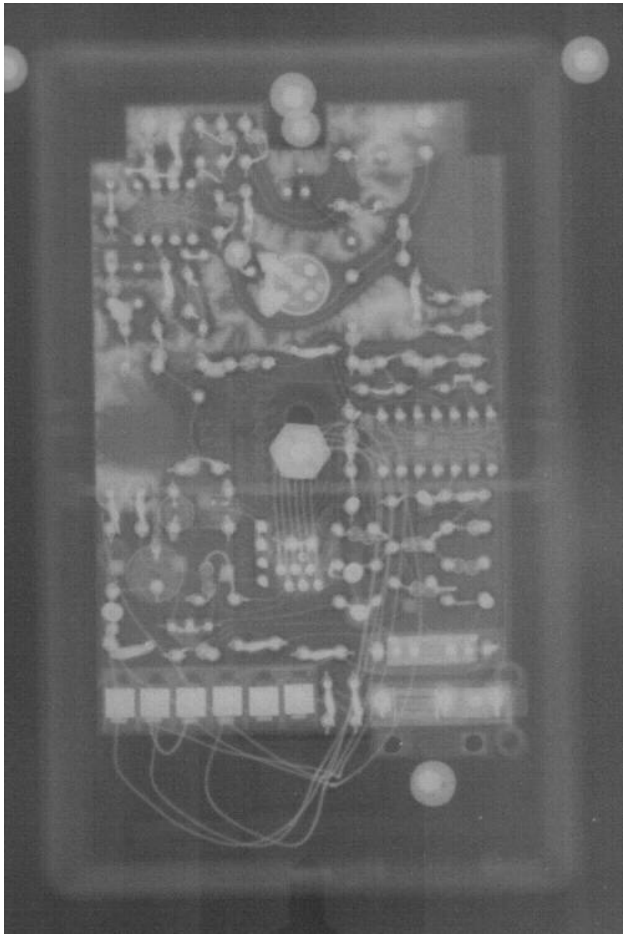
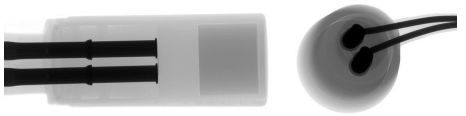
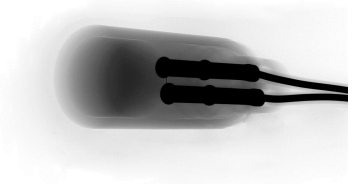


Challenge - Database





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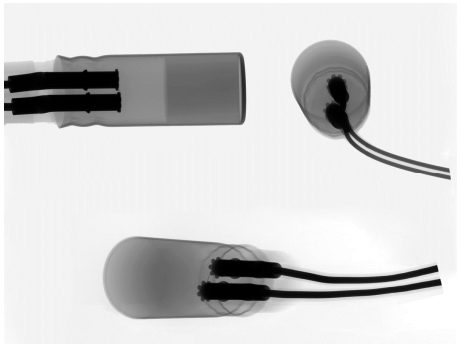

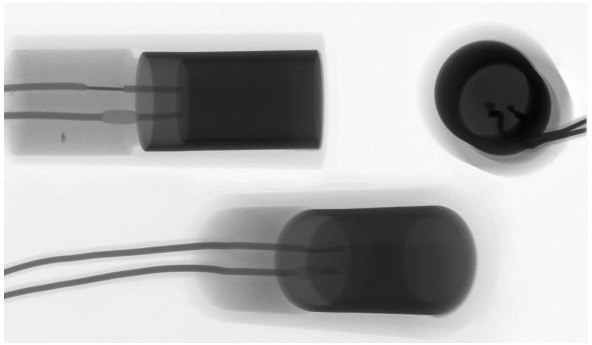

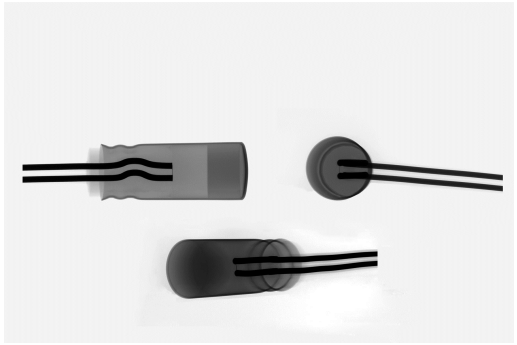

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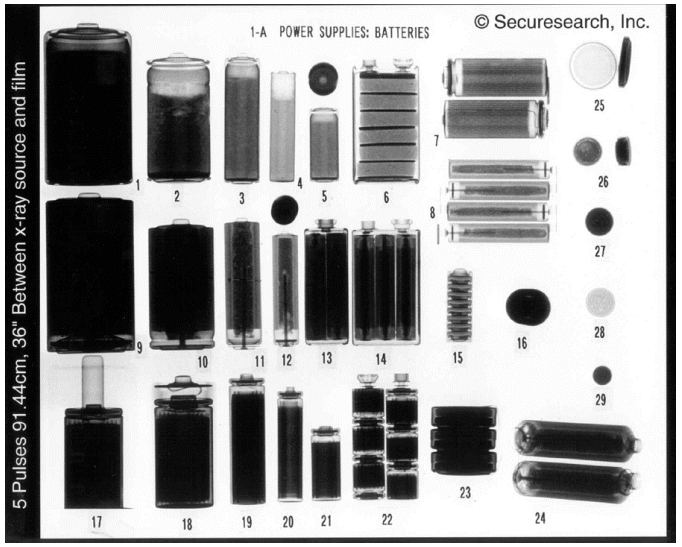

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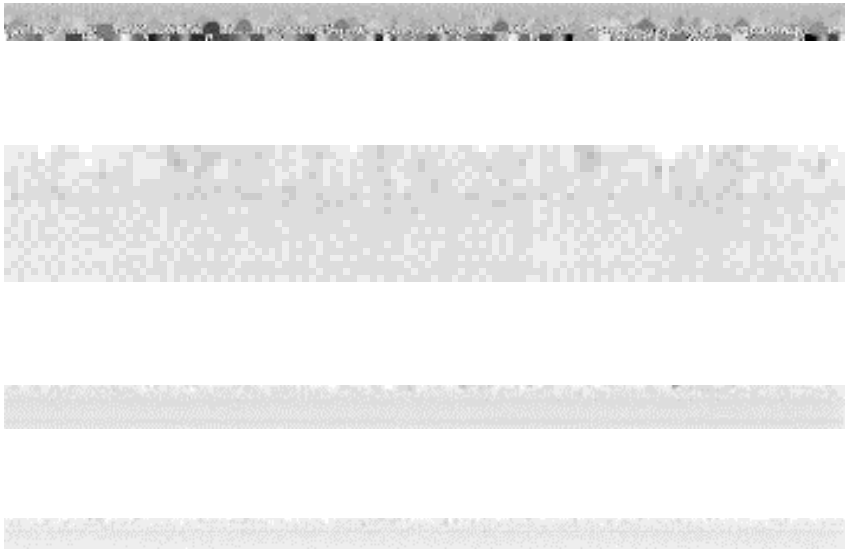

So why THIS Database?

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- Contains images of certain types of components
- ~17K images
- Metadata
  - Type
  - Main Material
- Continually updated

Background

- Bray et al.
  - "Exploring the feasibility of traditional image querying tasks for industrial radiographs" (2015)
  - Layering approach
- David G. Lowe
  - "Distinctive image features from scale-invariant keypoints" (2004)
  - Scale-invariant feature transform (SIFT)
  - Scale, Noise, Illumination
- Bay et al.
  - "SURF: Speeded Up Robust Features" (2007)
  - Faster than SIFT, but less accurate

SIFT

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- Scale invariant feature transform
- Interest points
  - Convolved with Gaussian filters at various scales (expensive)
  - Minima/maxima Difference of Gaussians at different scales define points
- Advantages
  - Identify objects in clutter
  - Partial Occlusion
- Disadvantage
  - Very slow due to computational complexity
  - Performance degradation with blurring

- Source: http://artofthehome.com/wp-content/uploads/2011/04/sifting-flour.jpg

Surf

- Speeded Up Robust Features (Bay et. Al.)
- Based on SIFT
- Generally several times faster than SIFT
- Three main parts:
  - Interest Point Detection
  - Local Neighborhood Description
  - Matching

- Source: http://www.surfingindia.net/files/surf-files/u9/India_Surf_Tours_-_17__1_.jpg

JESJ1
JESJ2

IPD

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- Square filters
  - Approximate Gaussian Smoothing
  - Detect Scale Invariant Feature Points
- Blob Detector
  - Interest points found at various scales
  - Hessian Matrix to get points of interest
  - At point p=(i,j), the Hessian at p and scale σ

$$H(p,\sigma) = \begin{bmatrix} L_{ii}(p,\sigma) & L_{ij}(p,\sigma) \\ L_{ij}(p,\sigma) & L_{jj}(p,\sigma) \end{bmatrix}$$

Slide 17

JESJ1 Jimenez, Edward Steven Jr, 8/24/2016

JESJ2 Jimenez, Edward Steven Jr, 8/24/2016

- Local Neighborhood Descriptor
  - Provides unique and robust description of an image feature
  - Balance between computational complexity and robustness/accuracy
  - Based on the sum of Haar Wavelet Responses

- Matching
  - Compare Descriptors from different images
  - Matching pairs → Matching Features

Harris-Stephens Algorithm

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- Corner Detection Algorithm
- Less focused on extracting image features, but rather detecting edges
- Corners are defined as interest points the weighted sum of squared differences is high
- Not to be confused with Laplace-Harris which is more of a blob detection algorithm
- Tested as many objects in the database are rectangular in shape
- Sharp edges present in database as well
- Will fail on circular objects?

MSER

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- Maximally Stable Extremal Regions
- Blob Detection algorithm
  - Find similarities from images with different viewpoints
- Advantages
  - Invariance to affine transformations (objects wrt position of image acquired)
  - Multi-Scale Detection (x-ray magnification)
  - Scale and Rotation invariant
- Disadvantage
  - Blurring (not relevant for our application)

Approach

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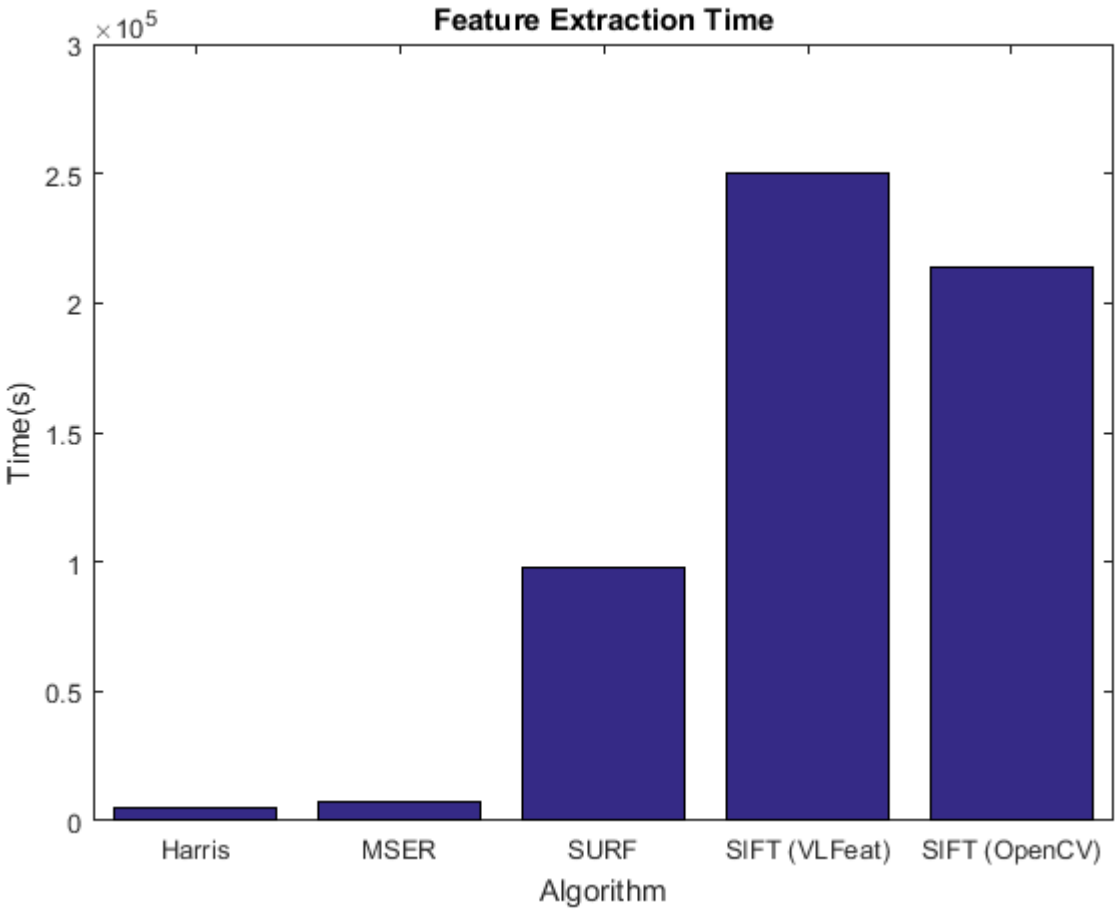
- Compare performance of out-of-the-box algorithms
  - Time
  - Accuracy
- Matlab
  - Computer Vision Toolbox
    - SURF
    - MSER
    - Harris
  - VLFeat
    - SIFT
- Python
  - OpenCV
    - SIFT

Implementation

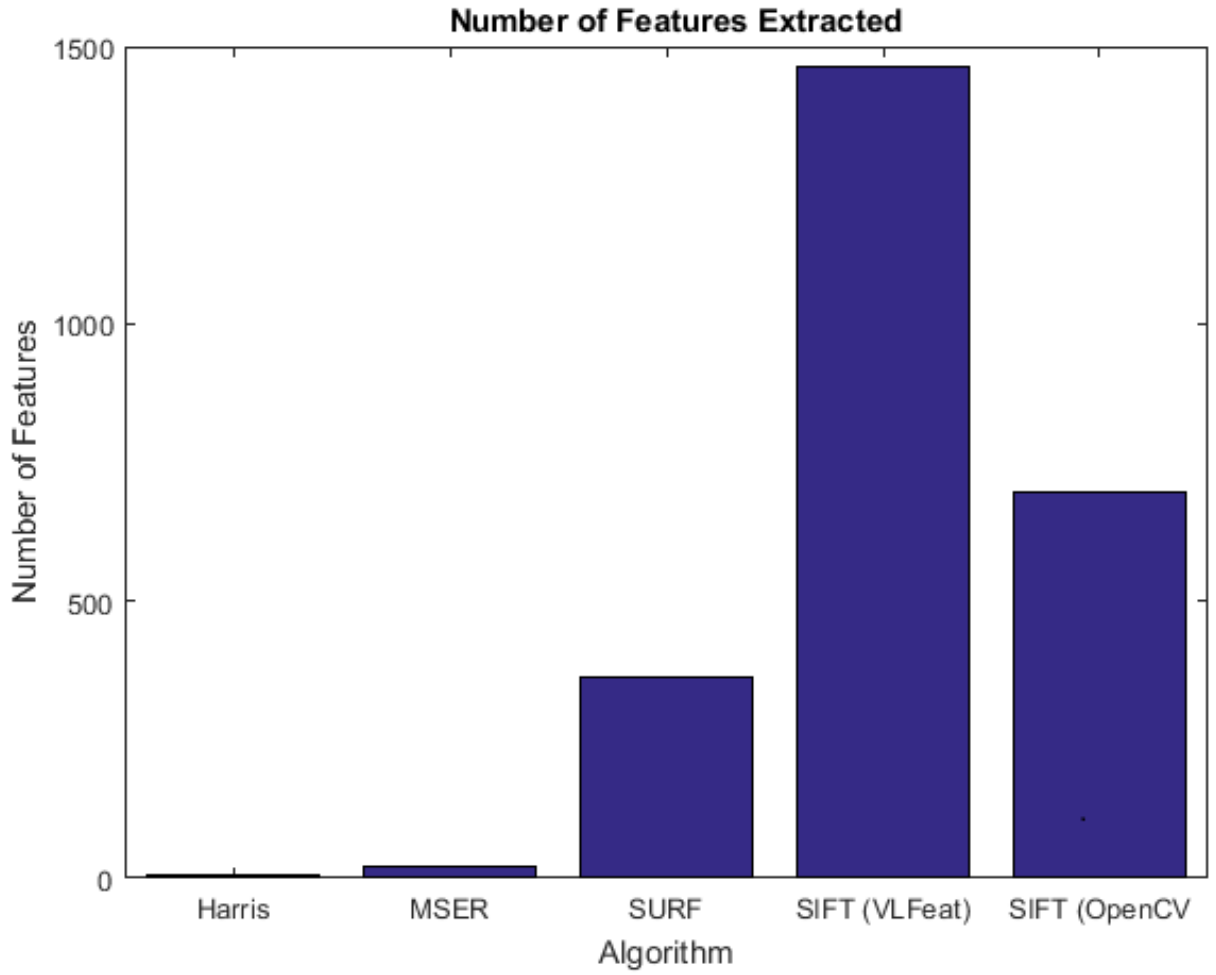
- Running on a Dell PowerEdge R920
  - 4 Intel Xeon E7-4820 v2 CPUs at 2.0 GHz (64 Cores Total)
  - 512 GB DDR3 RAM
- Matlab version R2016a
  - Computer Vision System Toolbox
  - Image Processing Toolbox
  - VLFeat version 0.9.20
- Python version 3.5.2
  - OpenCV version 2.4.13
- Used 3250 of ~17K images
  - 325 objects with 10 images each

Source: http://en.community.dell.com/cfs-file/__key/communityserver-wikis-components-files/00-00-00-01-62/PowerEdgeR920.png

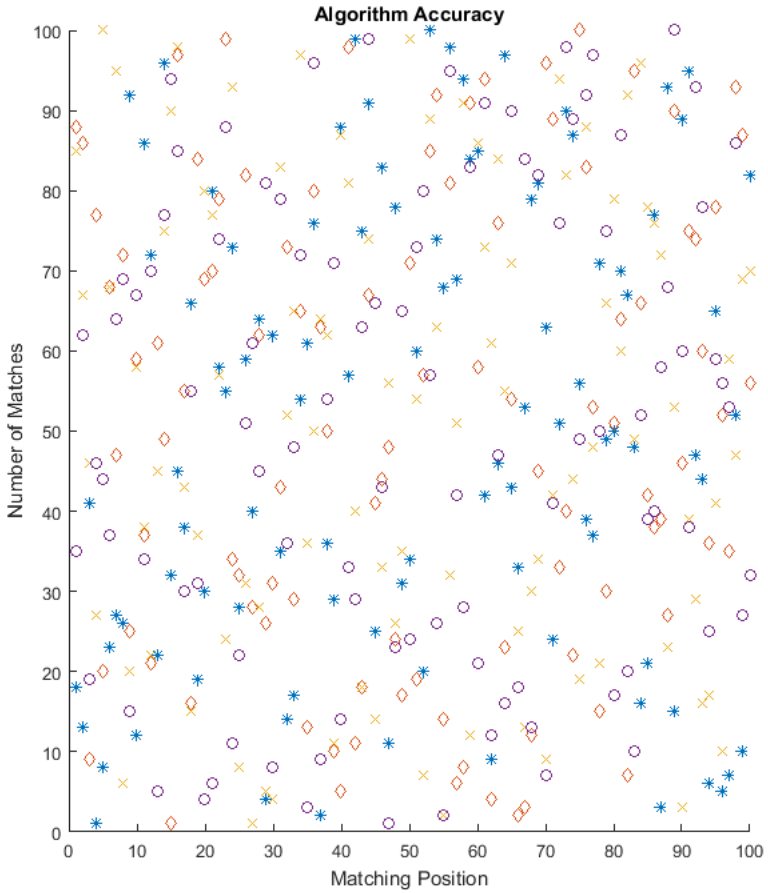
Results


Feature Extraction Time
×10^5
3
2.5
2
1.5
1
0.5
0
Time(s)
Harris
MSER
SURF
SIFT (VLFeat)
SIFT (OpenCV)
Algorithm

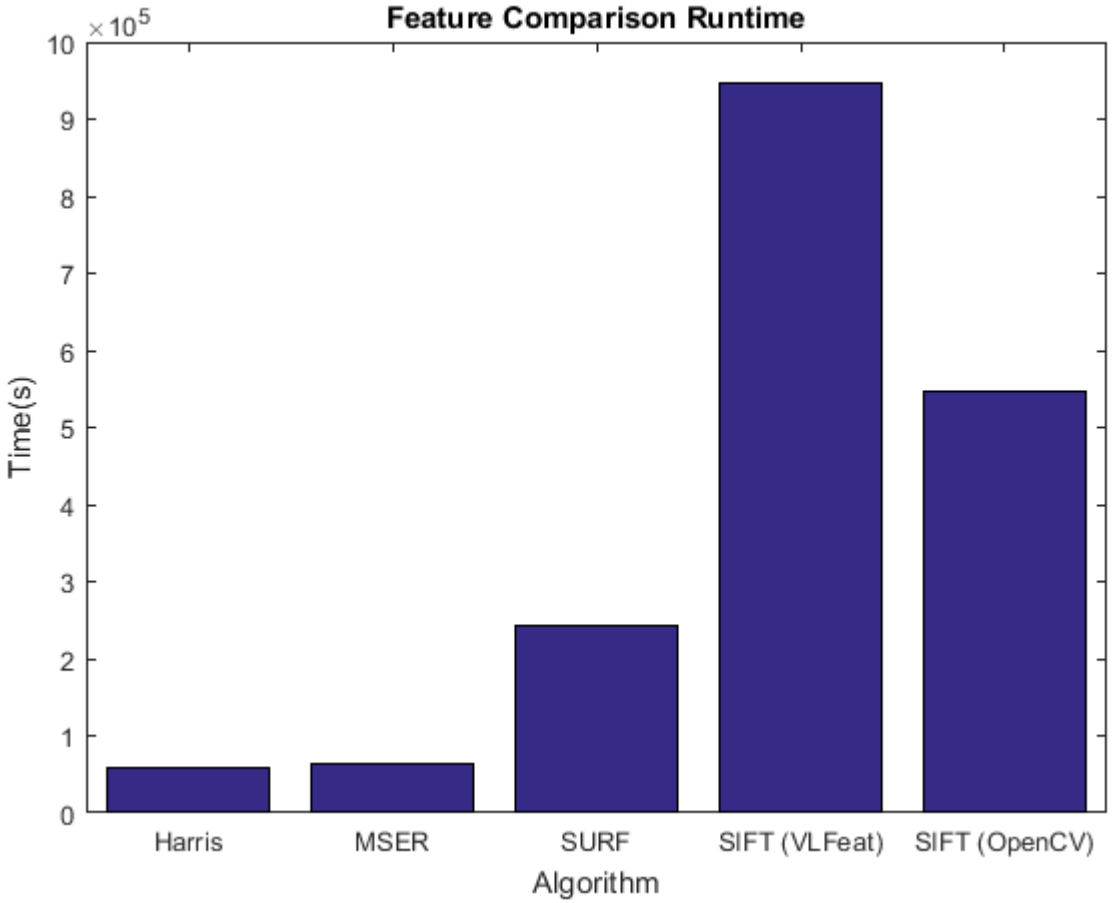
Results


Number of Features Extracted
1500
1000
500
0
Number of Features
Harris
MSER
SURF
SIFT (VLFeat)
SIFT (OpenCV
Algorithm

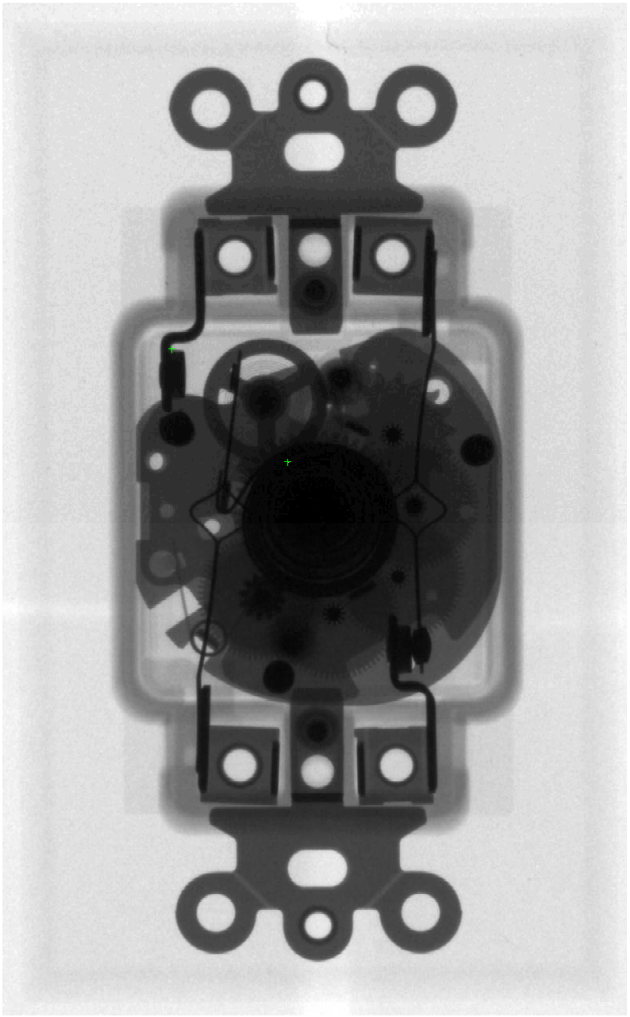
Results


Algorithm Accuracy
Number of Matches
Matching Position
0
10
20
30
40
50
60
70
80
90
100

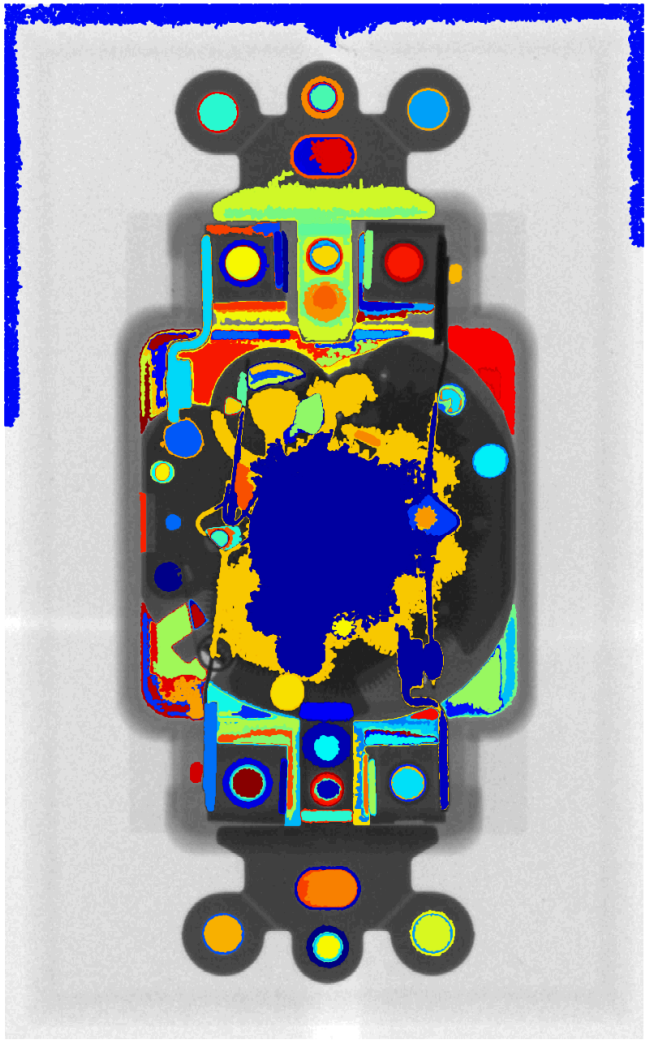
Results


Feature Comparison Runtime
×10^5
10
9
8
7
6
5
4
3
2
1
0
Time(s)
Harris
MSER
SURF
SIFT (VLFeat)
SIFT (OpenCV)
Algorithm

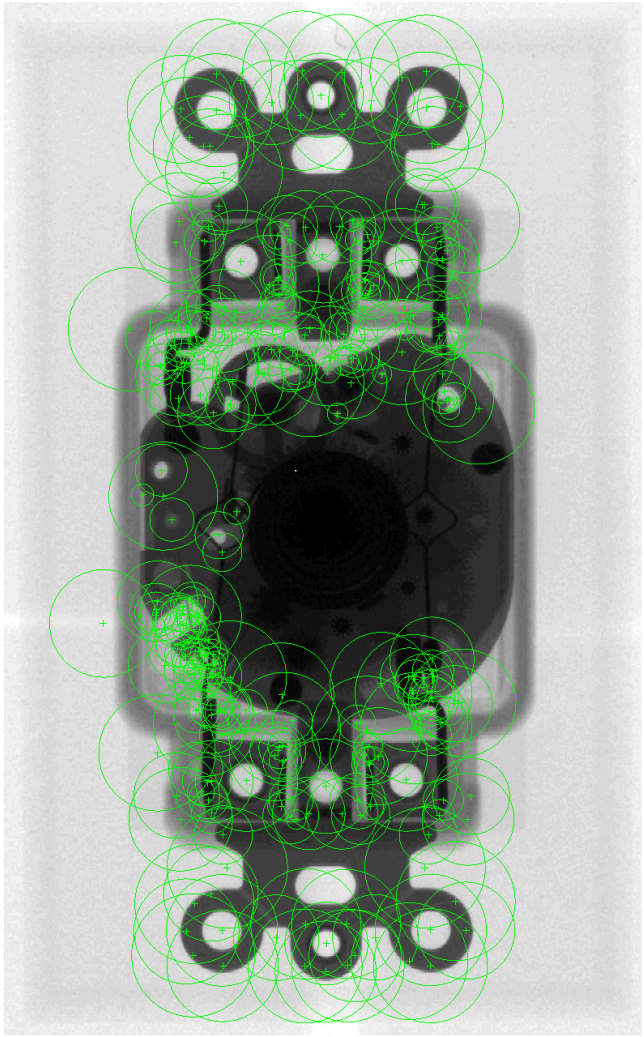
Results - Harris



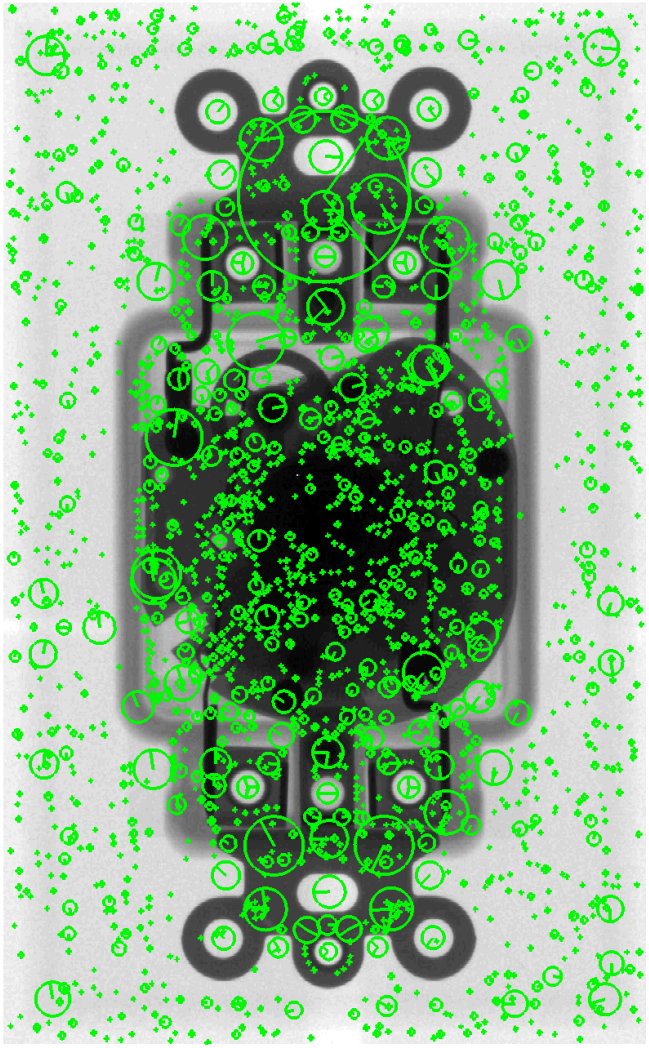
Results - MSER



Results - SURF



Results - SIFT



Results

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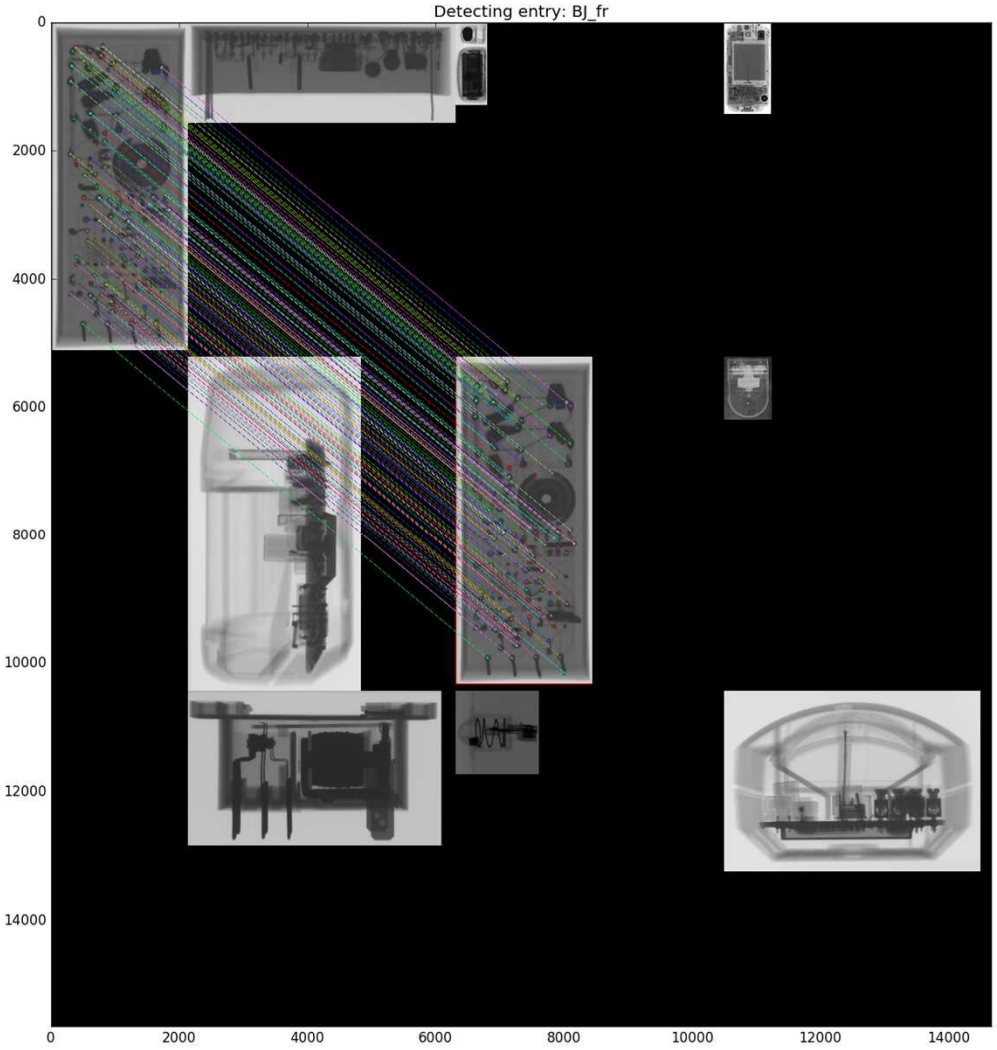
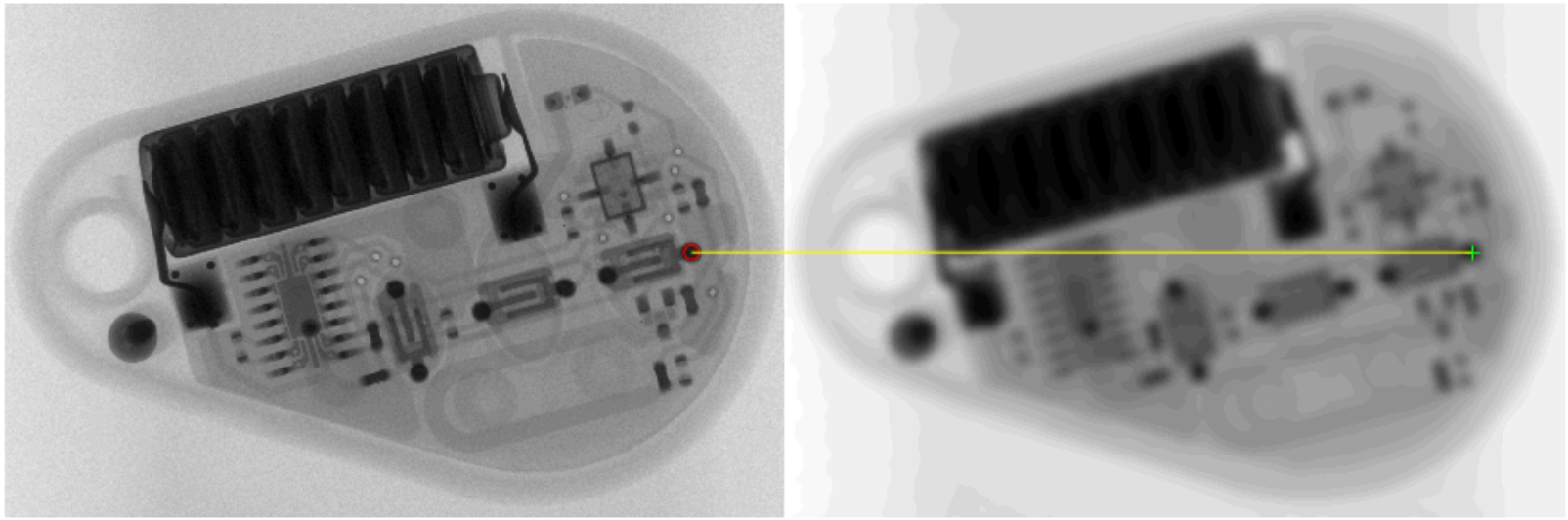
Algorithm	Average # of features extracted
Harris	4
MSER	10
SURF	120
SIFT	255

Results


Detecting entry: BJ_fr
0
2000
4000
6000
8000
10000
12000
14000
0
2000
4000
6000
8000
10000
12000
14000

Results

- Blurring



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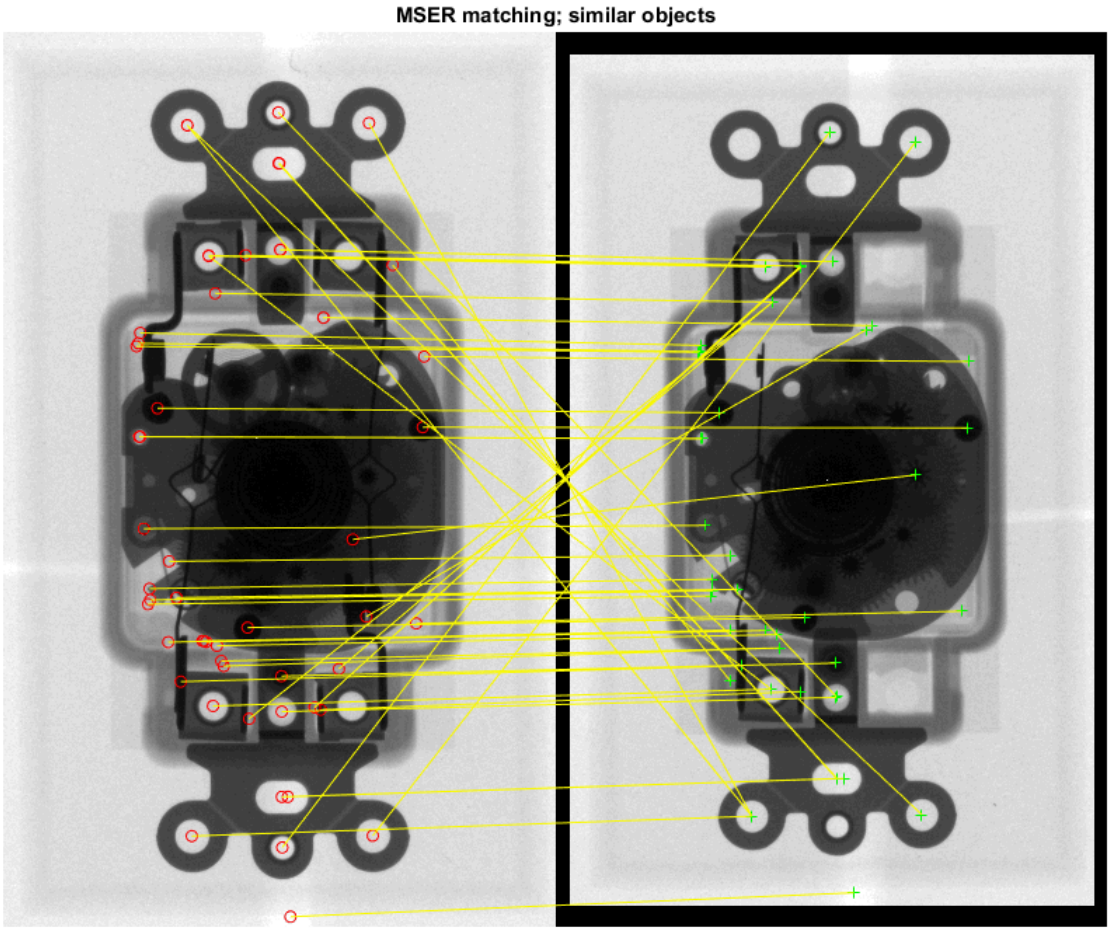

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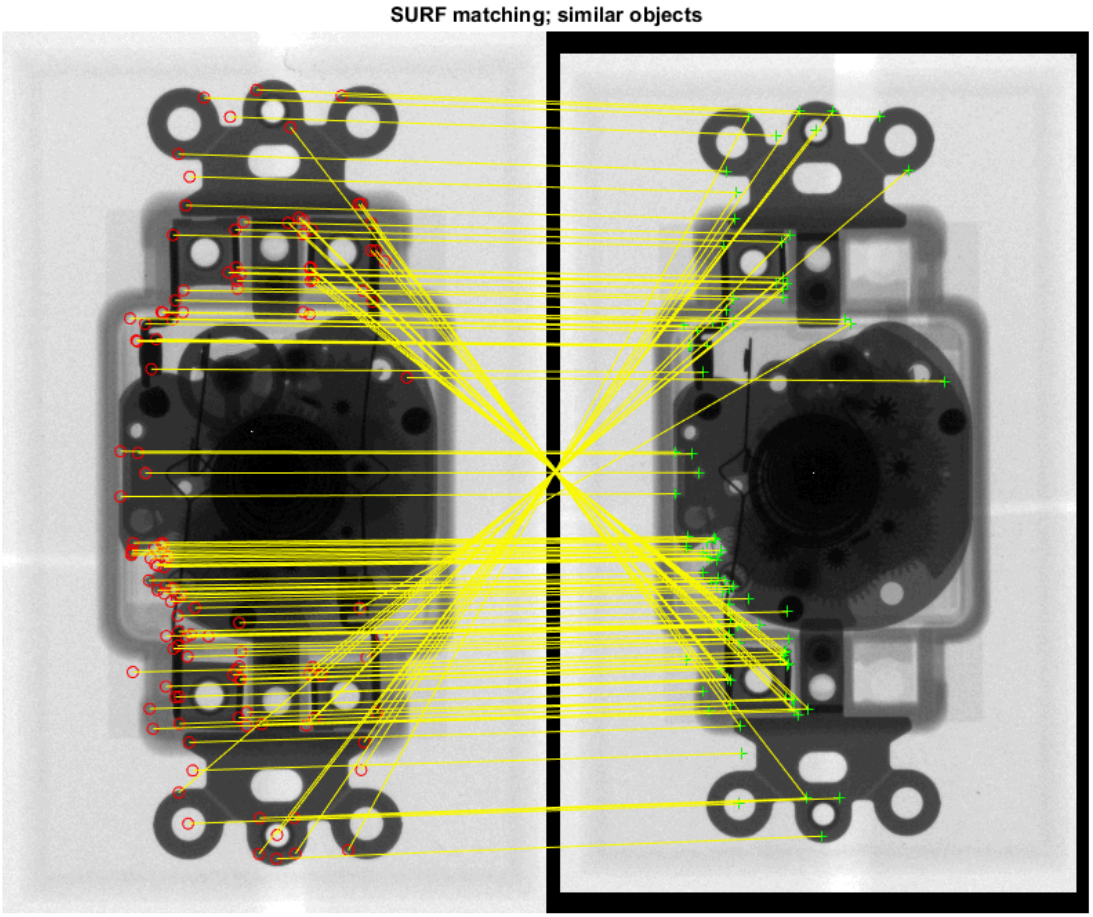

Results

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Algorithm	Our Results	Original Results
SIFT	25%	55%
SURF	23%	50%
MSER	20%	40%
Harris	15%	25%

Conclusion

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- Accuracy Sift > SURF > MSER > Harris
- Performance is a big challenge
  - All perform slowly
  - ||Sift|| > ||SURF|| > ||MSER|| > ||Harris||
- There are shortcomings and there is room for improvement
- Our particular database makes computer vision challenging
  - Better quality data may yield better results
- Many of the shortcomings of the various algorithms are valid in the x-ray imaging modality as well as many of the advantages
- These algorithms do hold a lot of promise in the x-ray modality for the same reasons they are valid for photography

Future Work

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- Narrow down which algorithms work best for radiographs
- Investigate more algorithms based on SIFT
- Create hybrid algorithm which will work for real-world images