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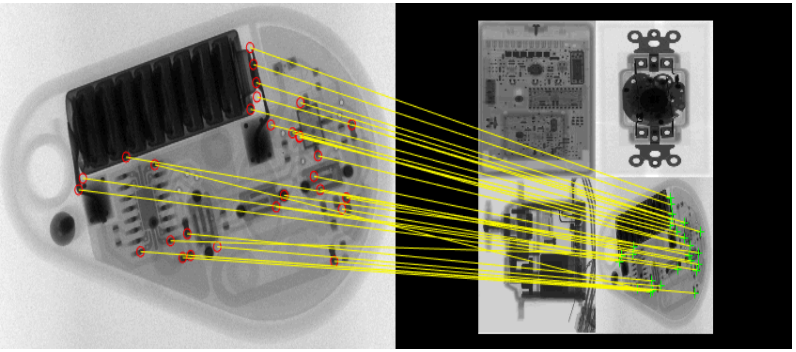

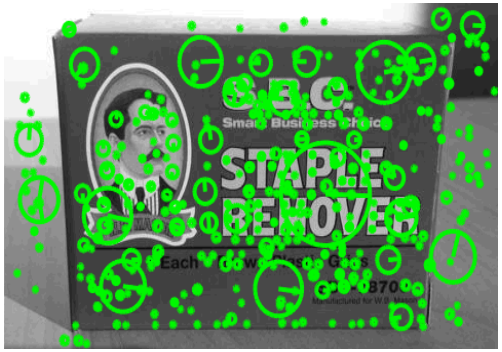

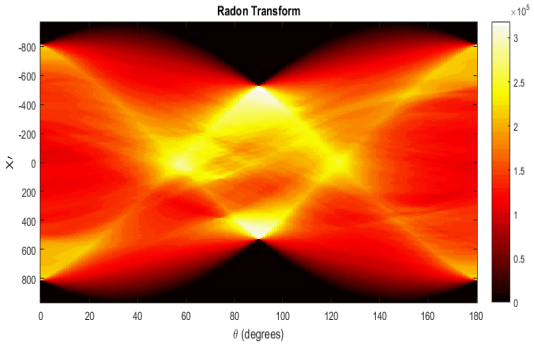

Object Recognition in X-ray Radiographs

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Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration

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Introduction

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- Objective
  - Develop the ability to perform image-based queries on a database of a collection of component radiographs
  - Matching under various conditions (noise, occlusion, out-of-plane rotations, etc.)
- Obstacles
  - Most computer vision work done with visible-light photographs in mind
  - Difficulties posed by X-ray penetration
    - Occlusions
    - Lack of color information
  - Working with our database
    - JPG compression
    - Extraneous images
    - No labelling

Background

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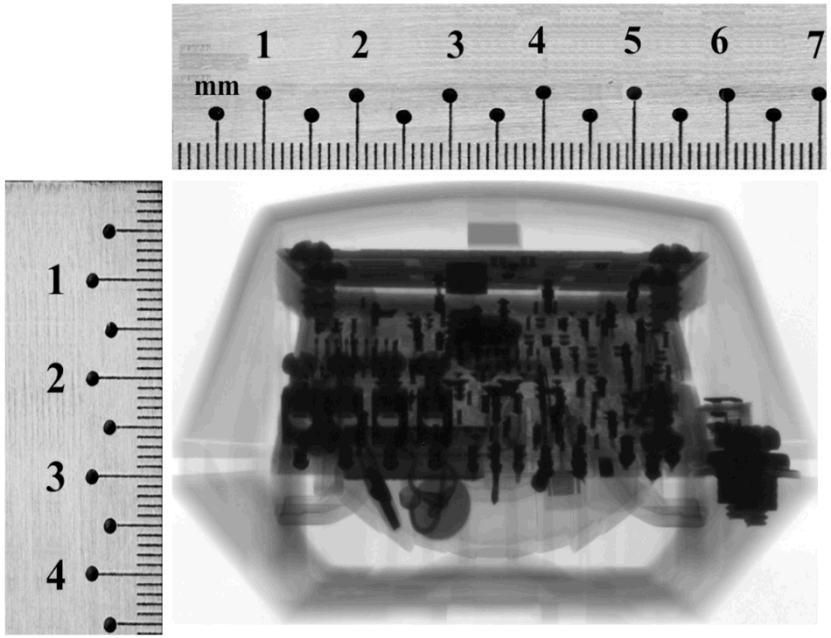
- Database preparation (past work)
  - Removing irrelevant images
  - Cleaning radiographs
- Feature detectors/descriptors
  - SIFT
  - SURF
  - MSER
- Image segmentation
  - Global Otsu Method

Background – Database preparation

- Not originally intended for object recognition
- Example images from the database

Visonic Duet

Bosch DS840T RZ



Background – Database preparation

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- Bray et al. (2015)
  - Removed duplicate data using commonalities in the naming scheme.
  - Separated photographs from radiographs by checking color/greyscale information.
  - Segmented out extraneous objects from the radiographs (rulers, text, etc.).
  - Database was manually checked to verify that it was successfully cleaned.

Background – SIFT/SURF

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- SIFT – Scale Invariant Feature Transform
  - David G. Lowe (2004)
  - One of the most widely used feature detectors/descriptors
  - Invariant to:
    - Affine transformations (scale, translation, etc.)
    - Noise
    - Rotation (slightly)
- SURF – Speeded Up Robust Features
  - Inspired by SIFT
  - Specifically designed to be significantly faster than SIFT
- SIFT: accurate
- SURF: fast

Background – MSER

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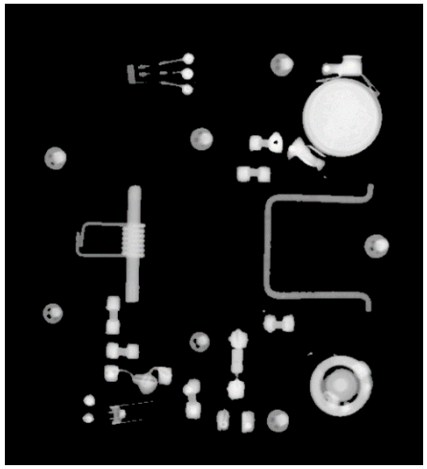
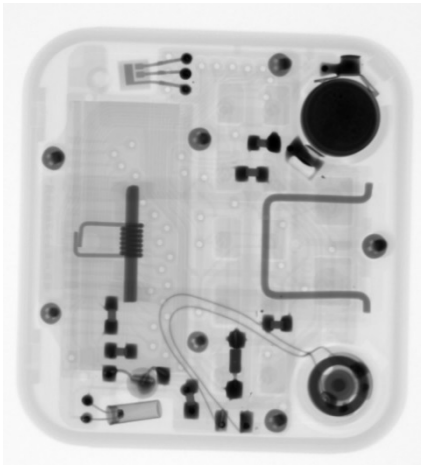
- MSER – Maximally Stable Extremal Regions
  - Used for "blob" detection
  - Detects regions of uniform intensity values
  - Described using enclosing ellipses
- Can be particularly in radiographs since intensity values are essentially the ONLY information provided.
- Possible implementations combine an MSER detector with a SIFT descriptor

Background – Segmentation

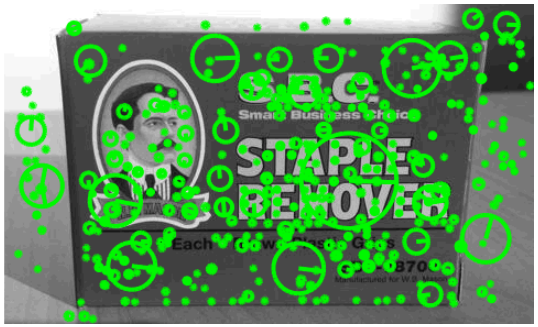
- So far, segmentation only intended to remove background
- Future work will look into separating various layers
- Global Otsu Method
  - Nobuyuki Otsu
  - Histogram cluster-based image thresholding
  - Attempts to minimize the in-class variance when segmenting the histogram





Background

- SIFT



- SURF

- MSER

Approach

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- Experiment
  - Test available software
    - MATLAB: Image Processing Toolbox, Computer Vision Toolbox
    - OpenCV (Python implementation)
    - VLFeat
- Apply
  - Determine ideal processing and recognition techniques for our specific database
- Expand
  - Experiment with advanced methods specific to X-rays
  - Research and develop alternative methods

Approach - Experiment

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- MATLAB
  - Image Processing Toolbox
    - MATLAB's system for reading/writing/editing images.
    - Contains many standard image processing and image analysis tools.
    - In our case, used mainly for filtering, segmentation, and morphological operations.
  - Computer Vision Toolbox
    - Contains implementations of the most common computer vision techniques.
    - Includes functions for object recognition, tracking, facial recognition, image registration, and various other tools.
    - We used this primarily for feature extraction and matching.

Approach - Experiment

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- OpenCV
  - Open source
  - Written in optimized C/C++
  - Has C++/C/Java/Python implementations
  - Extremely large range of tools
    - Image processing
    - Computer vision
    - Machine learning
    - Many more

Approach - Experiment

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- VLFeat
  - Open source
  - Written in C; interfaces in MATLAB/Python
  - Toolset less exhaustive than MATLAB/OpenCV
    - Supports some feature detectors/descriptors
    - Small number of image processing functions
    - Does have some statistics and data analysis tools
  - **Implements SIFT features**
    - By default, MATLAB and OpenCV (OpenCV > 2.4) don't have SIFT features
  - We specifically used this for the MATLAB implementation of SIFT features

Results – Noise (SIFT features)

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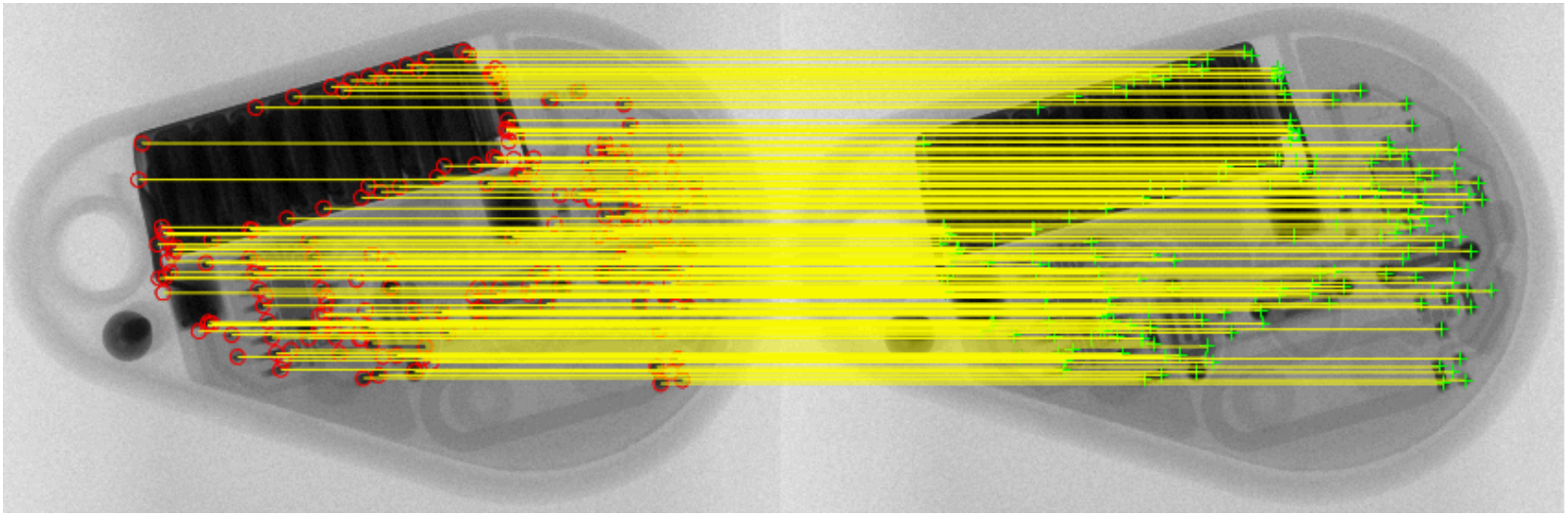

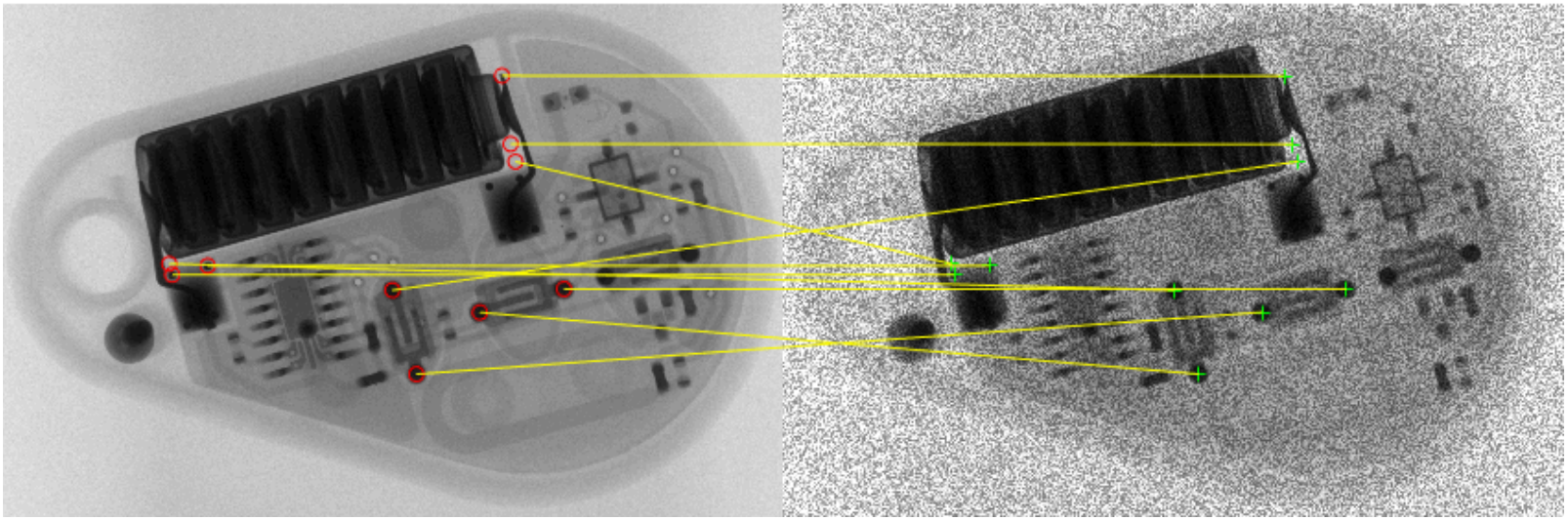

Results – Noise (SIFT features)

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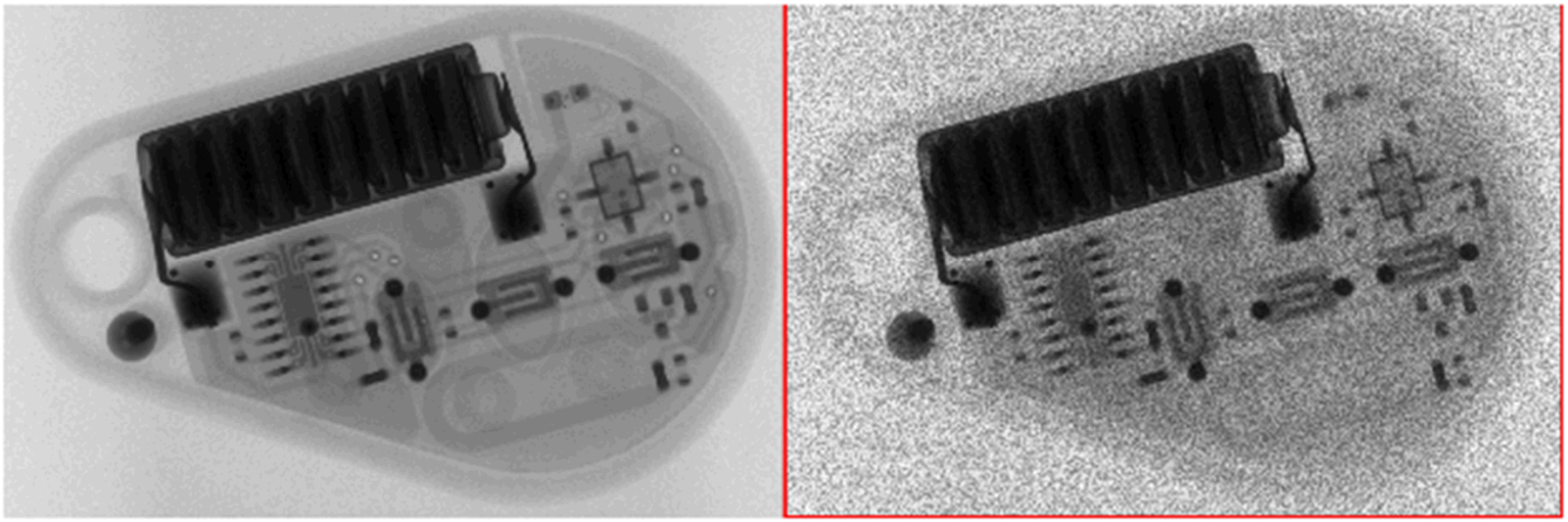

Results - Rotation (SIFT features)

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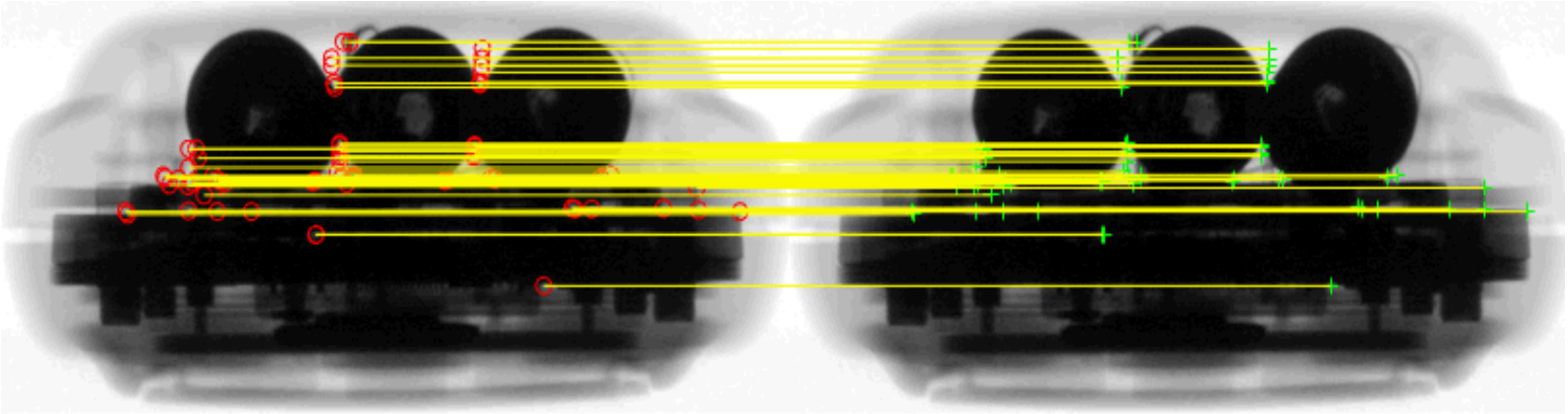

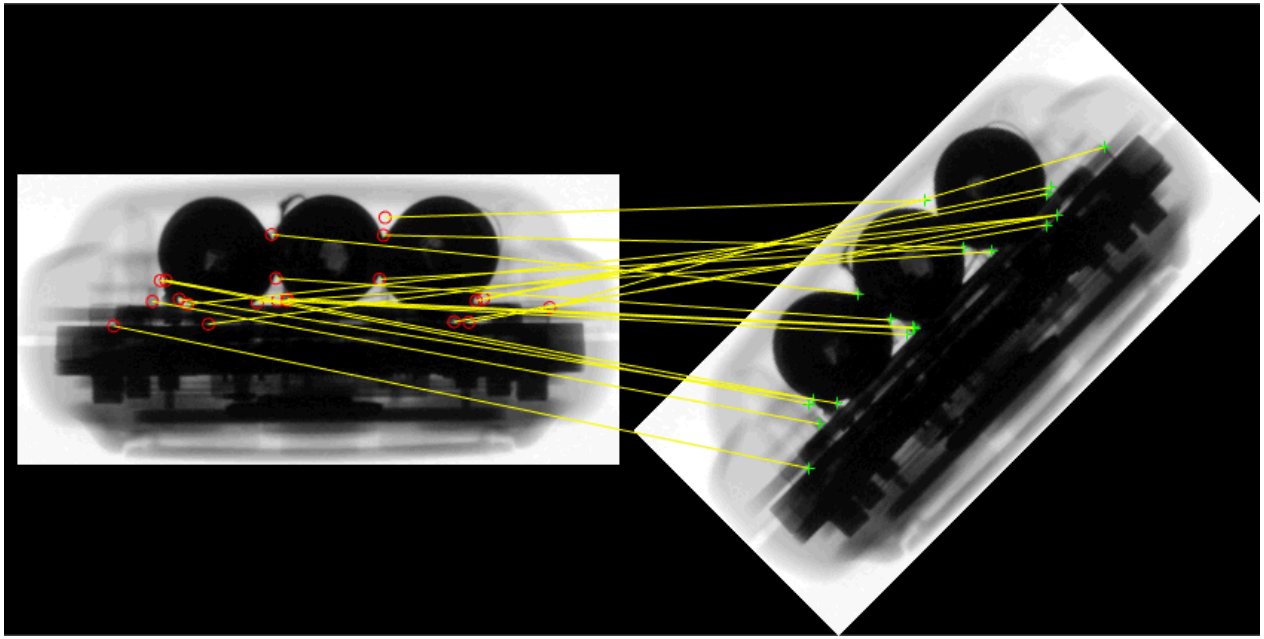

Results - Rotation (SIFT features)

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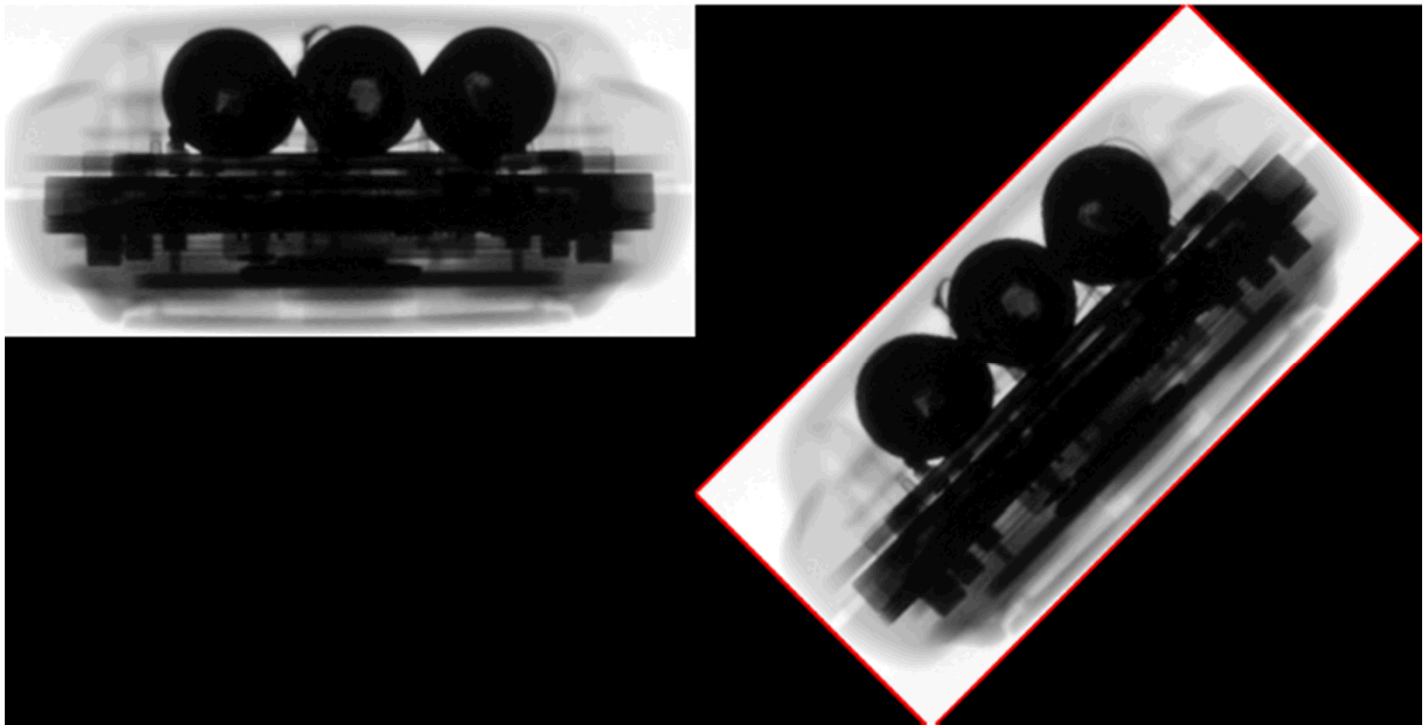
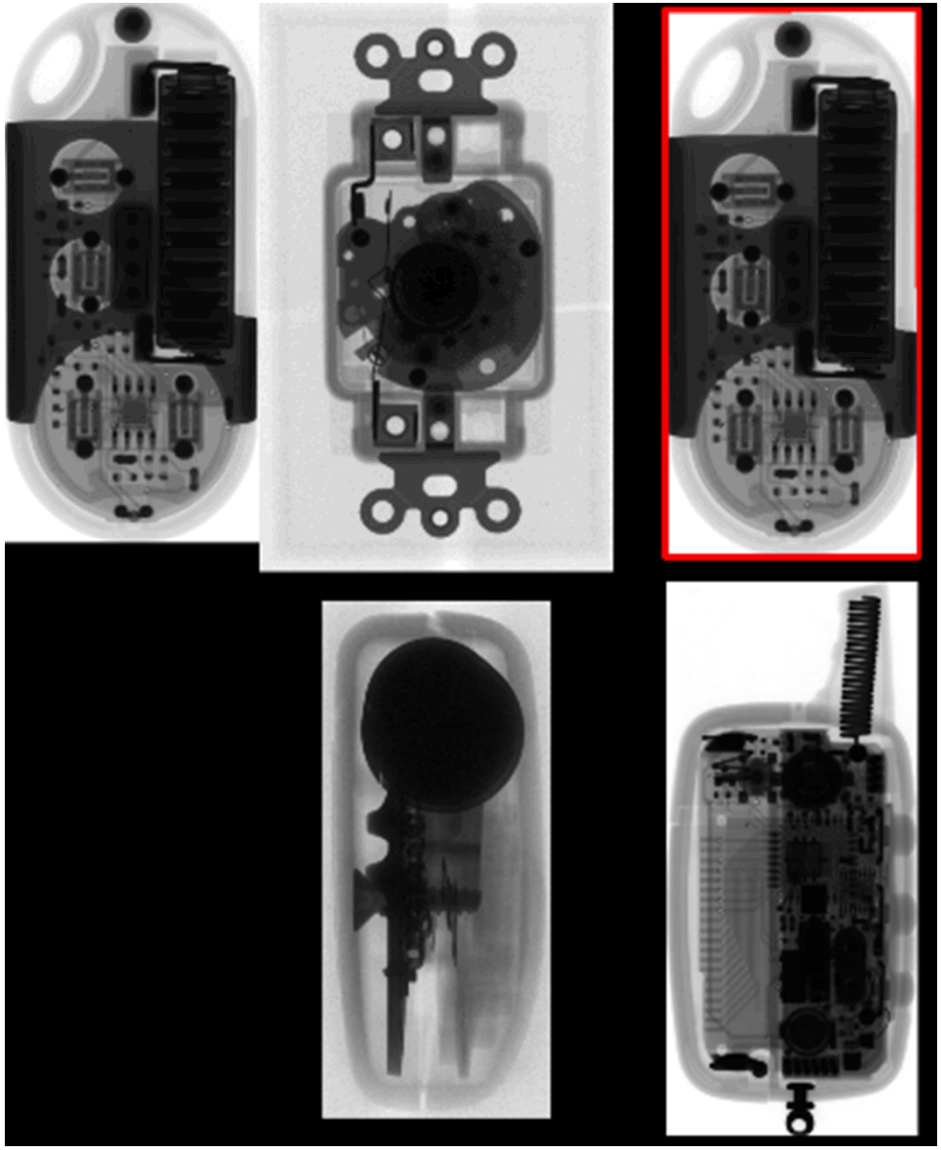


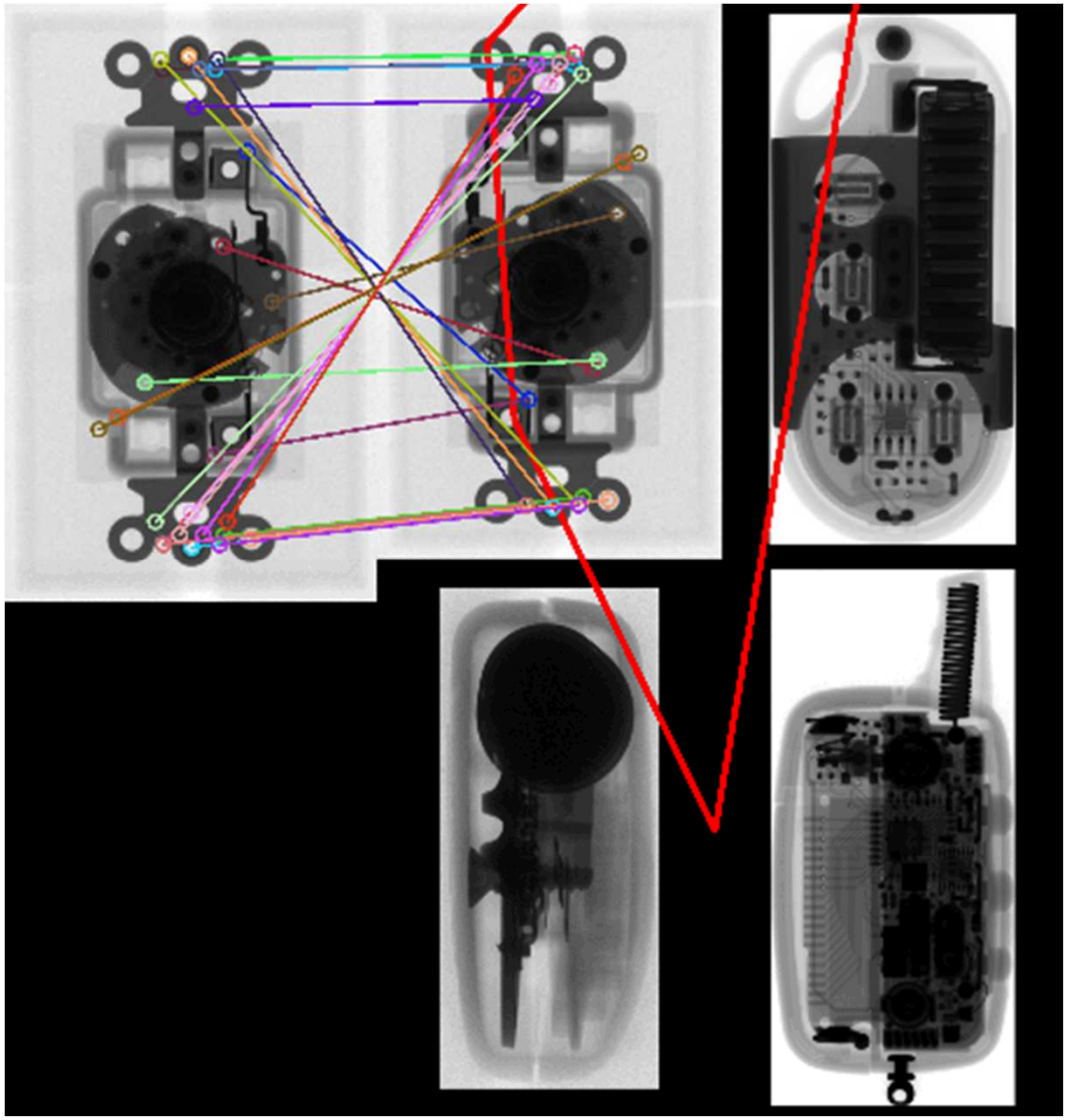
Results – Groups (SIFT features)

- Good match



Results – Groups (SIFT features)

- Skewed match
- Matched features drawn to emphasize cause of poor bounding box calculation



Results

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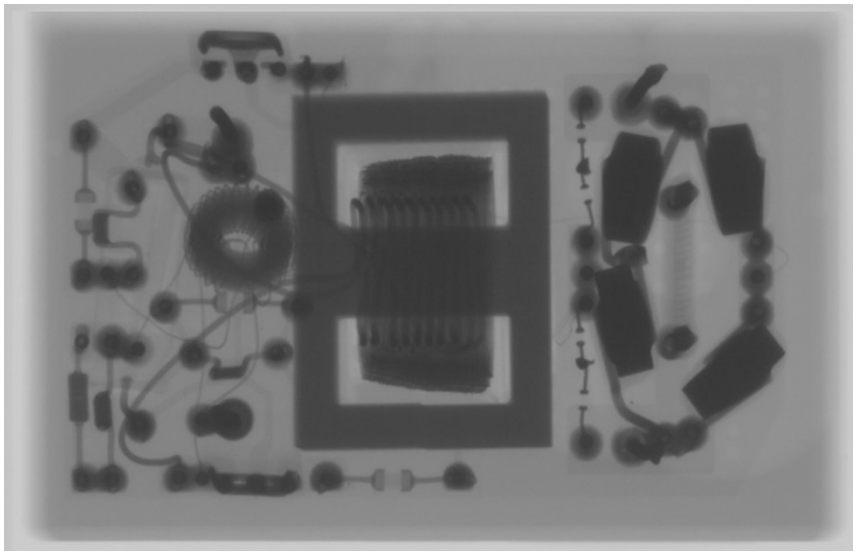
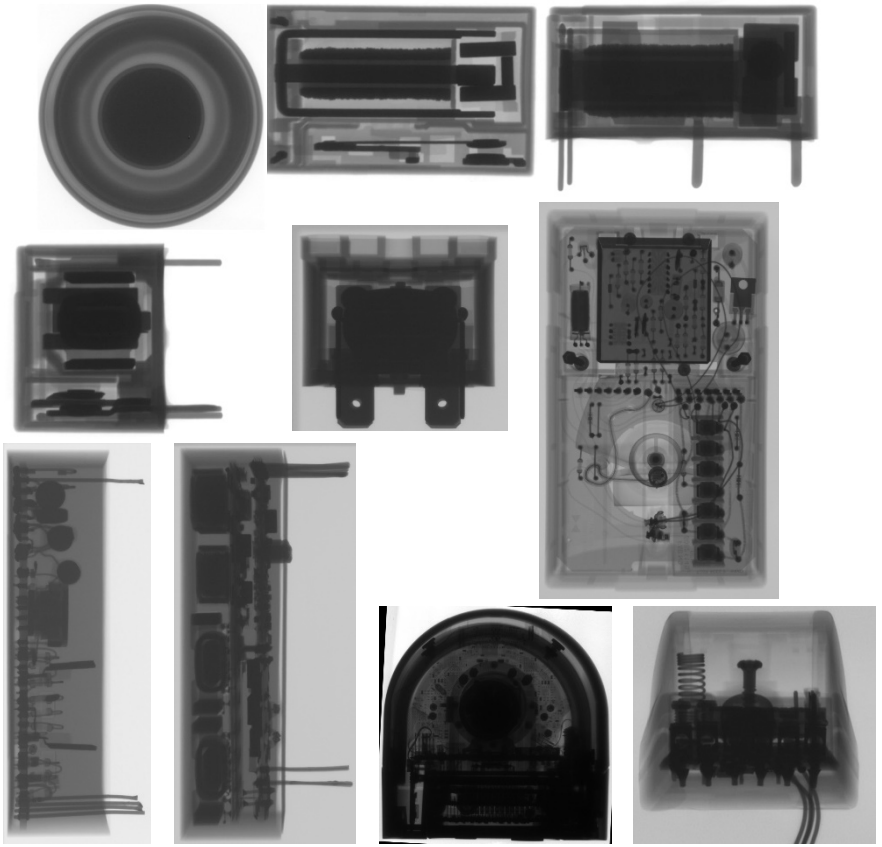
Test image



Top matches (not to scale)



Discussion

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- Strengths of algorithm
  - Handles simpler obstacles easily (noise, rotation, scaling)
  - Can positively detect objects even in groups
  - Segmentation removes background extremely well

- Weaknesses of algorithm
  - Can't match "similar" objects
  - Struggles with more difficult obstacles (occlusion, out-of-plane rotation, etc.)
  - Segmentation unable to handle transmission overlap

Future work – Bag-of-Words

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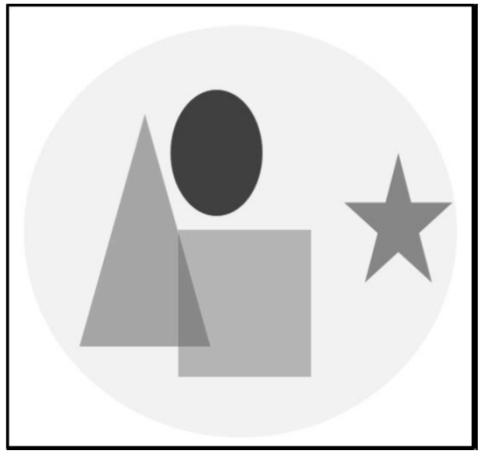
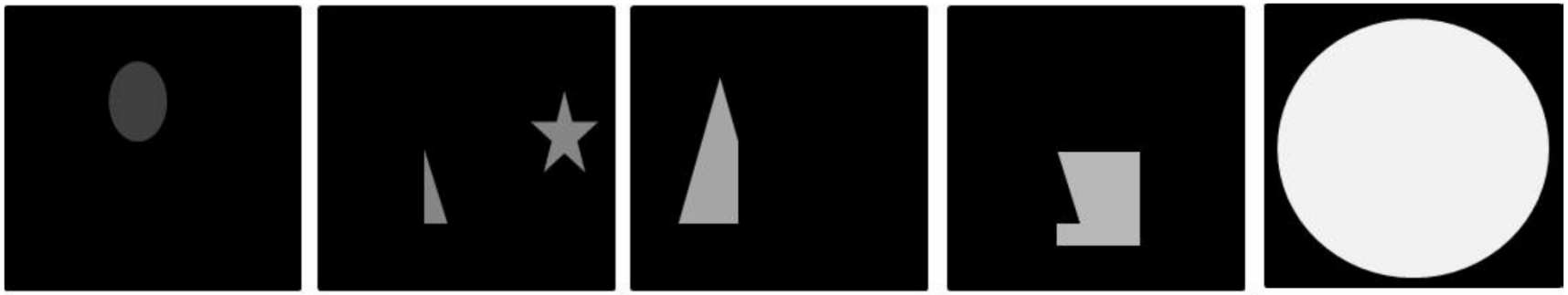
- Bag-of-Words
  - Initially designed for language processing and text analysis
  - Creates a simplified version of an object
    - e.g breaking down a paper about Christmas into key words such as “presents”, “tree”, “ornaments”, “lights”, etc.
  - Extended to computer vision
    - Instead of [document] and [key words], uses [image] and [features]
  - Pros
    - Able to match “similar” objects
    - Can detect multiple objects in a single image
  - Cons
    - Requires labelled images for machine learning

Future work – Segmentation

- X-ray penetration introduces segmentation problems that aren't present in photographs



- From Bray et al.:



Future work - MIFT

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- MIFT
  - Guo et al. (2010)
  - Variation on SIFT that is also invariant to mirror reflections
  - A comparison of MIFT (a) vs. SIFT (b)

- Just one example of how improvements to feature descriptors can greatly increase performance