Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by Battelle *Since 1965*

Feature Extraction in Three Dimensional Millimeter-wave Radar Imaging

JUSTIN FERNANDES

Applied Physics Group, NSD
Richland, WA

Conclusions

- Better data produces better algorithm performance
  - Enhanced coverage (viewing perspective)
  - Higher frequency (lateral resolution)
  - Wider bandwidth (range resolution)
  - Reduced clothing and multipath artifacts (clutter reduction)
- Focus is directed towards obtaining 3-D millimeter-wave image specific feature vectors
  - Better feature vectors will improve performance of classifiers
  - Three dimensional volumetric rendering reduced in dimensionality
- All methods are data-driven methods
  - Need to narrow scope to limited number of body types for initial development

Outline

- Overall approach to automatic target recognition (ATR)
  - Goal
  - Methods
- Previous work
  - 2-D feature extraction
    - Speckle detection
    - Man-made object detection
- 3-D millimeter-wave image based feature extraction process
  - Preprocessing
  - Anomaly detection
  - Anomaly classification
- Data requirements

ATR Approach

- Goal
  - Detect concealed weapons and/or explosives on individuals during security screening while maintaining privacy rights
- Algorithm performance improves as more data is collected
  - Enhanced coverage (viewing perspective)
  - Higher frequency (lateral resolution)
  - Wider bandwidth (range resolution)
- Exploit techniques to detect target objects
  - Intensity
  - Depth
  - Polarization
  - Views from multiple angles
  - Unique features of the objects (texture, etc)

Previous Work

- 2-D amplitude data feature extraction techniques
  - Speckle/dielectric detection
  - Man-made structure detection

Speckle Detector for Dielectric Objects

Approach

- Plastic objects produce speckle in millimeter wave images. Speckle is the result of interference between multiple reflections and has a granular appearance.
- A multi-layer perceptron (MLP) neural network with dilation and median window filters detects presence of speckle indicating probable plastic in image

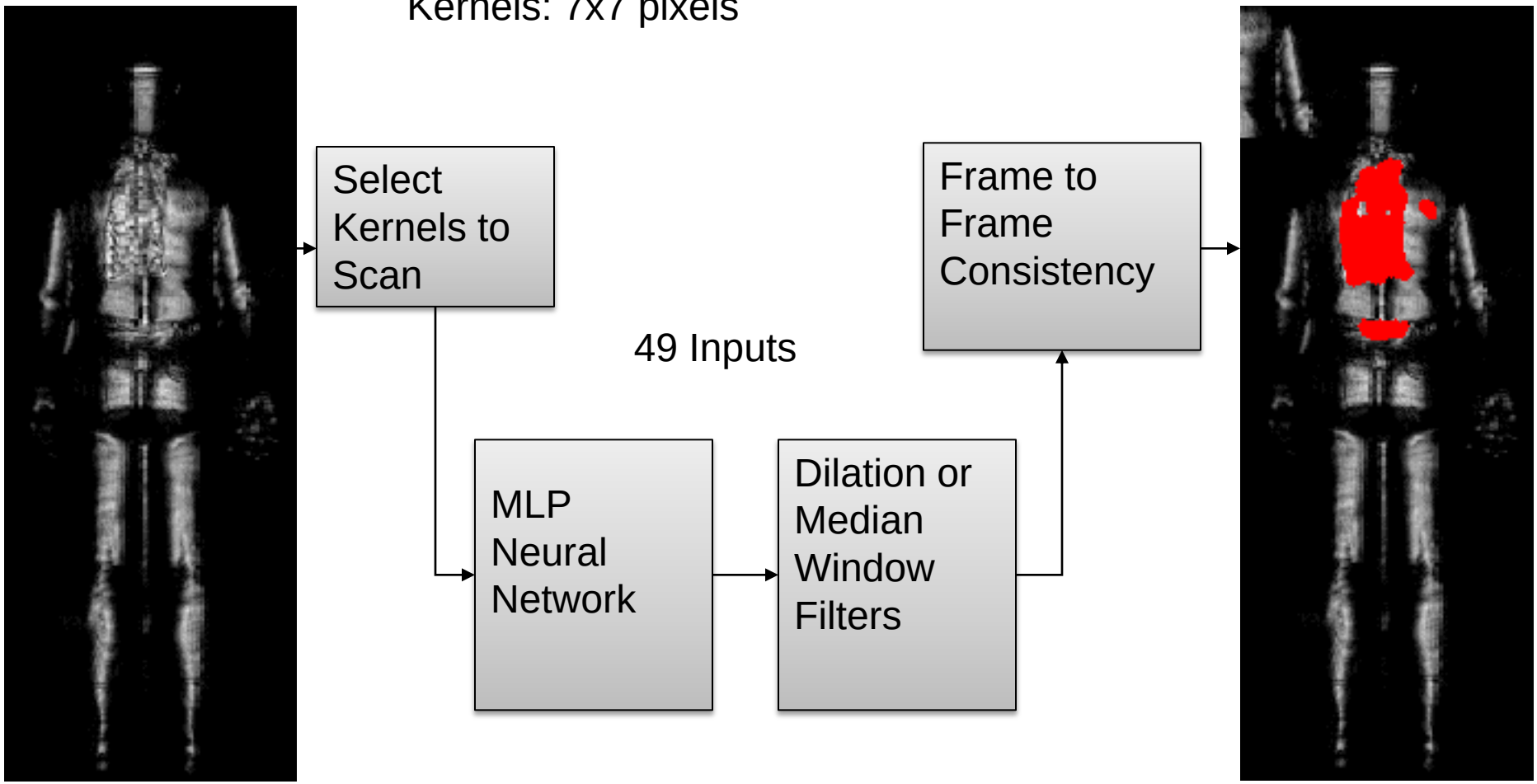
Goal

- Highlight speckle in images which is indicative of plastic (e.g., plastic guns, plastic explosives)

Data Sets

- SeaTac data and new scanner with new simulants

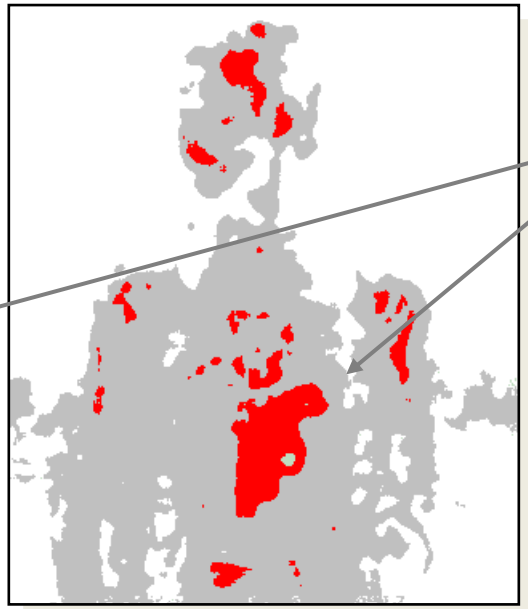
Speckle Texture Detector



Speckle Texture Detection Results with Plastic Flare Gun

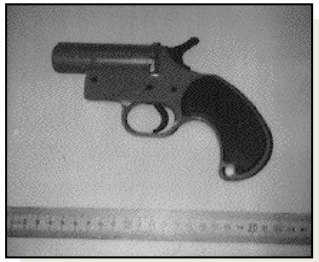
MM-wave image

Processed image



Plastic located

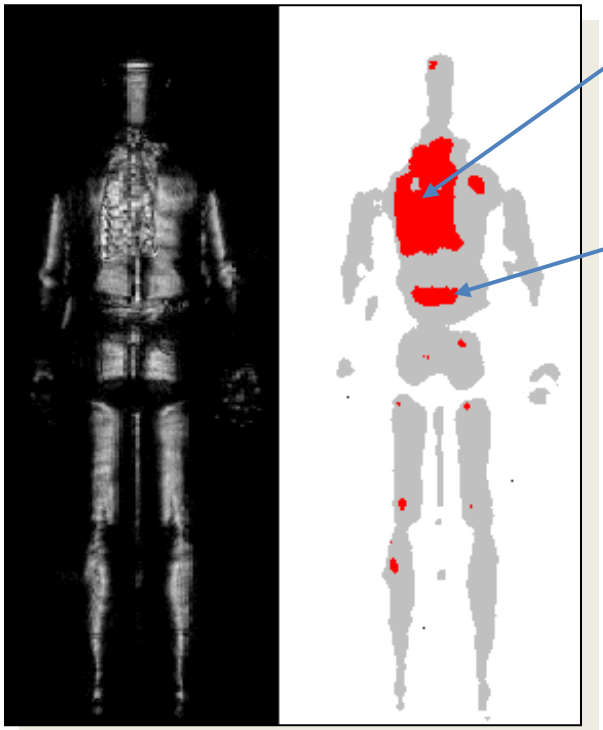
Flare Gun



Speckle Texture Detection Results on Simulated Plastic Explosive

- Filters remove stray hits and small areas (dilation, median, window)
- Frame to frame consistency also reduces false positives

Optical image

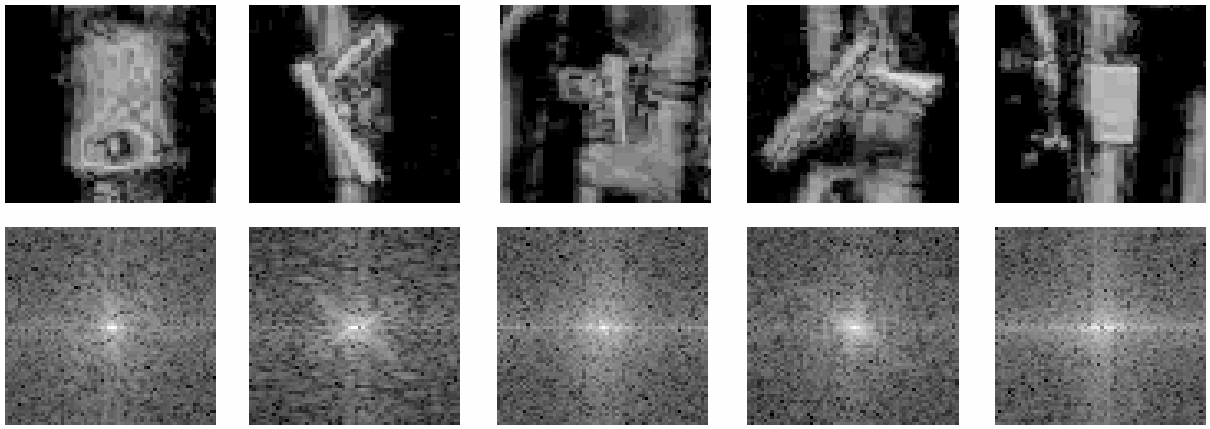


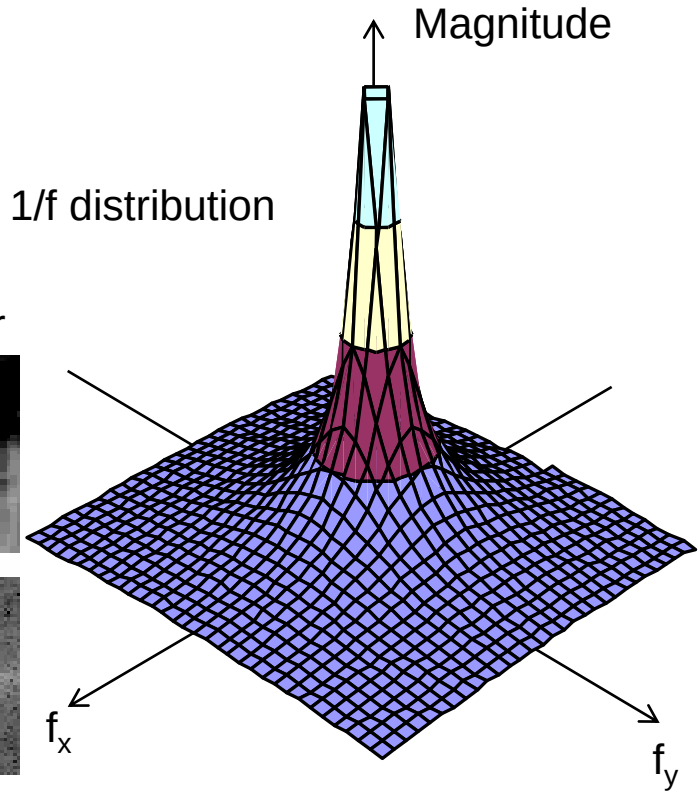
MM-wave image

Speckle detection algorithm

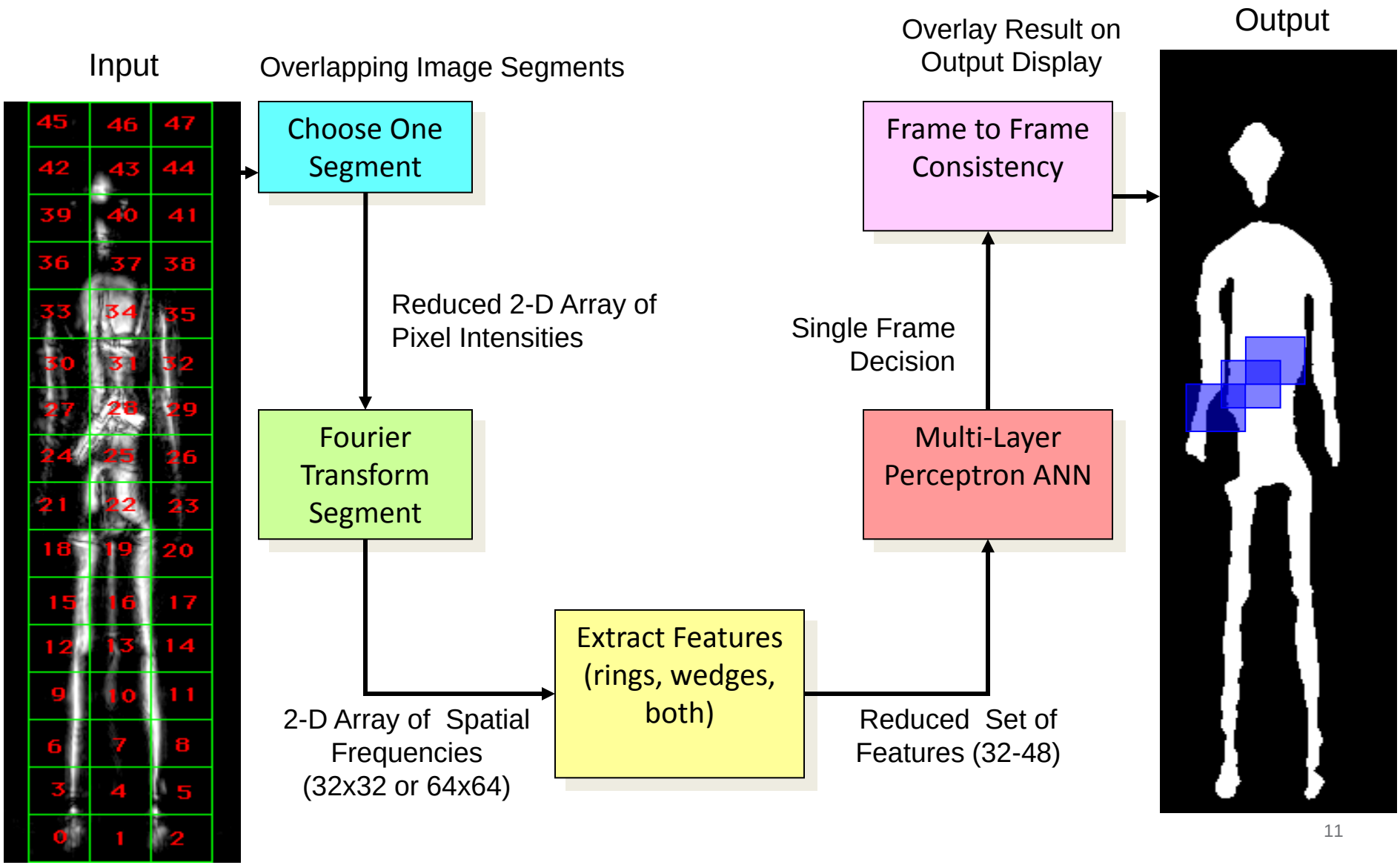
Observation About Man-made Objects: Higher Spatial Frequencies

- Man-made objects often have a higher percentage of high spatial frequency components than natural objects



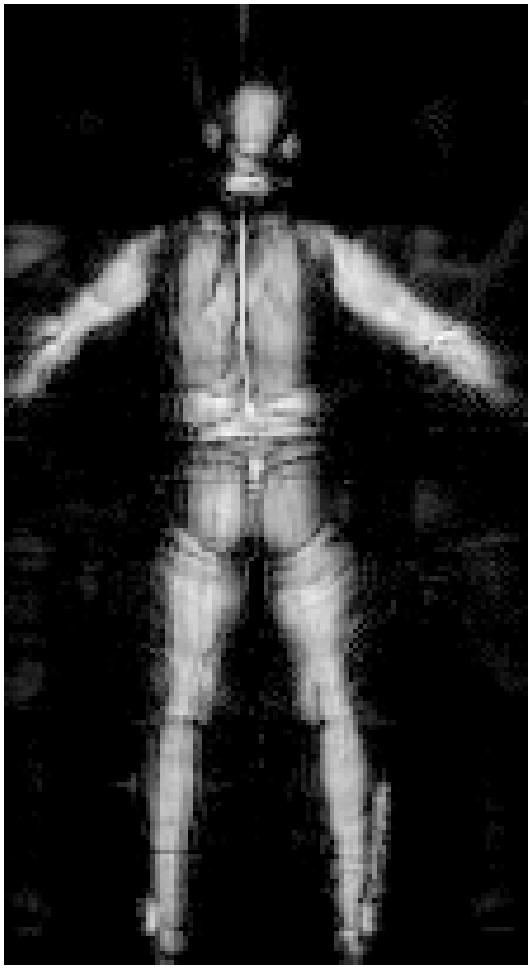


Overview of Man-made Structure Detector

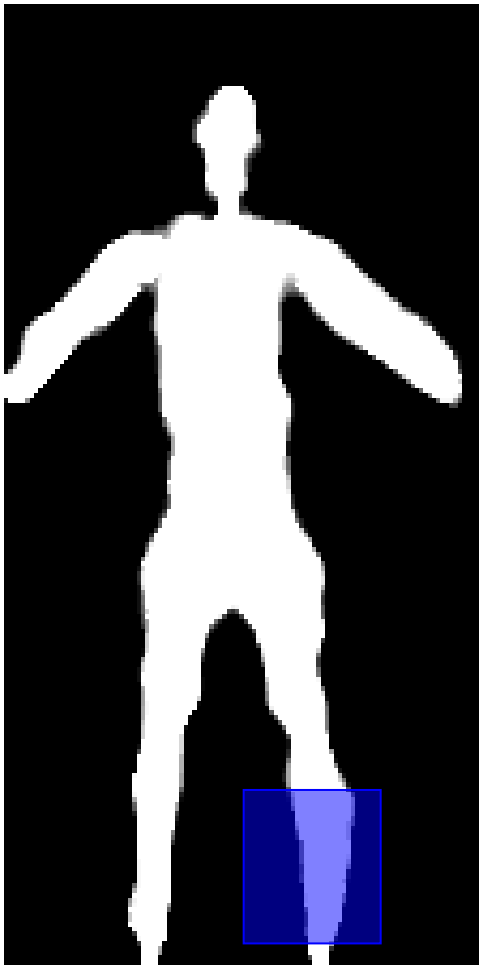


Concealed Knife on Outer Right Ankle

Optical photo

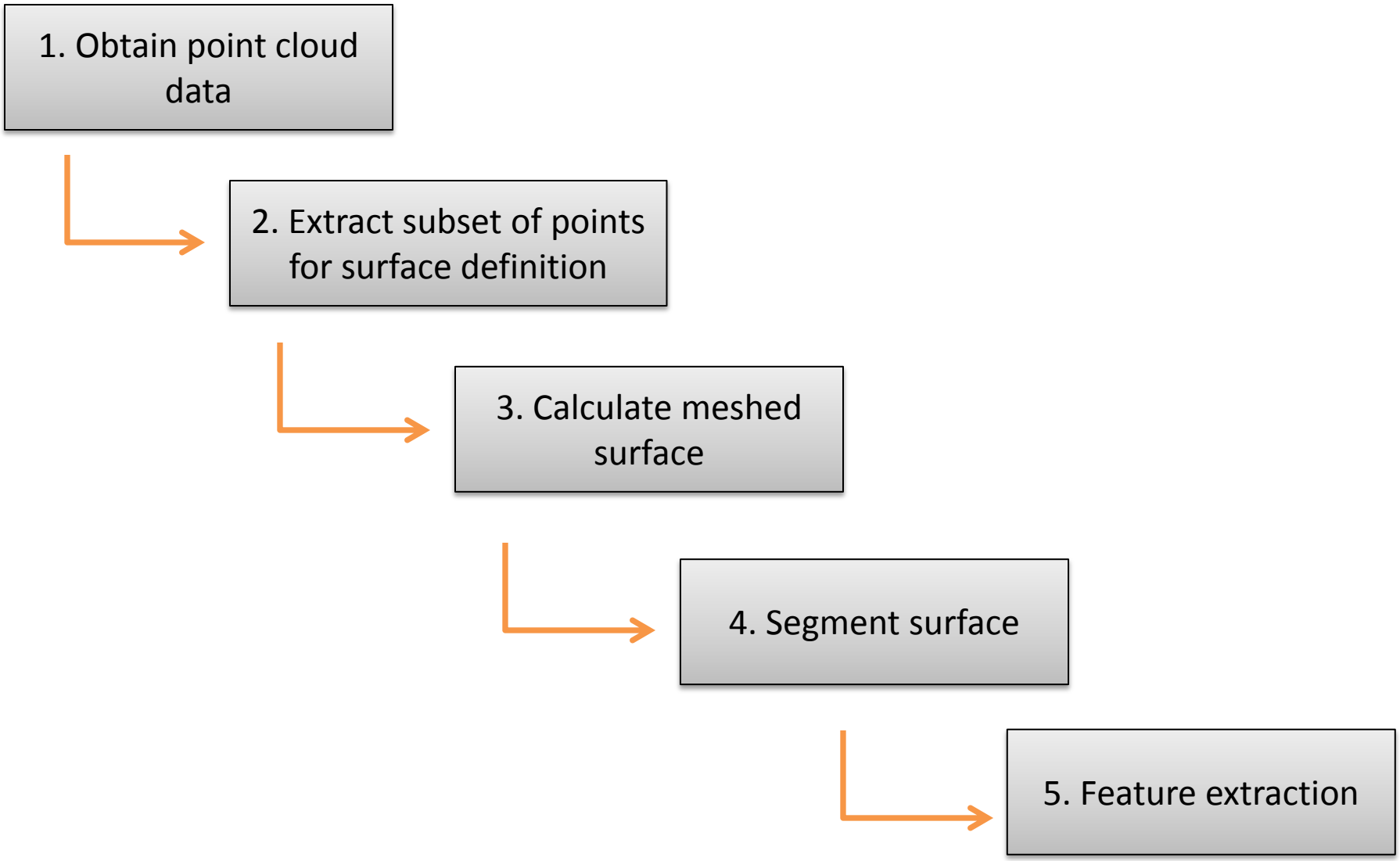


MM-wave image



Displayed output

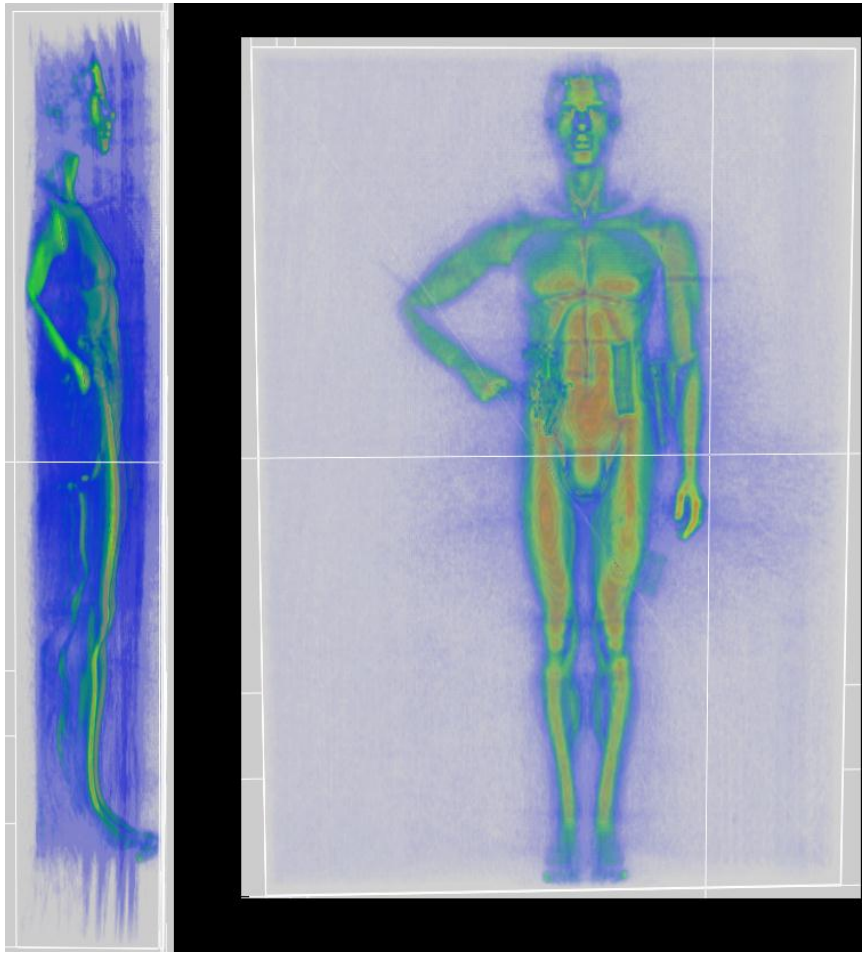
Automatic Target Recognition Process



Cylindrical Scan Target Scenario

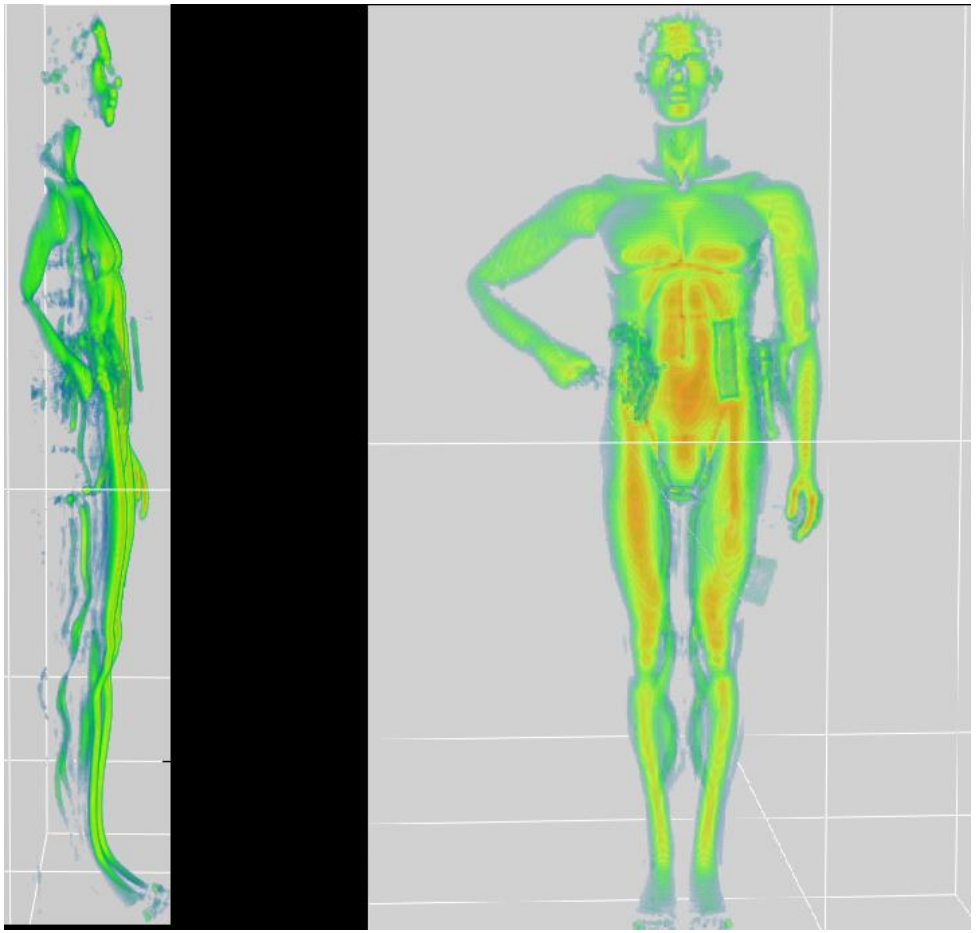
1. Obtain Point Cloud Data

- Front and side views of 3-D point cloud
- Each voxel represents reflectivity value



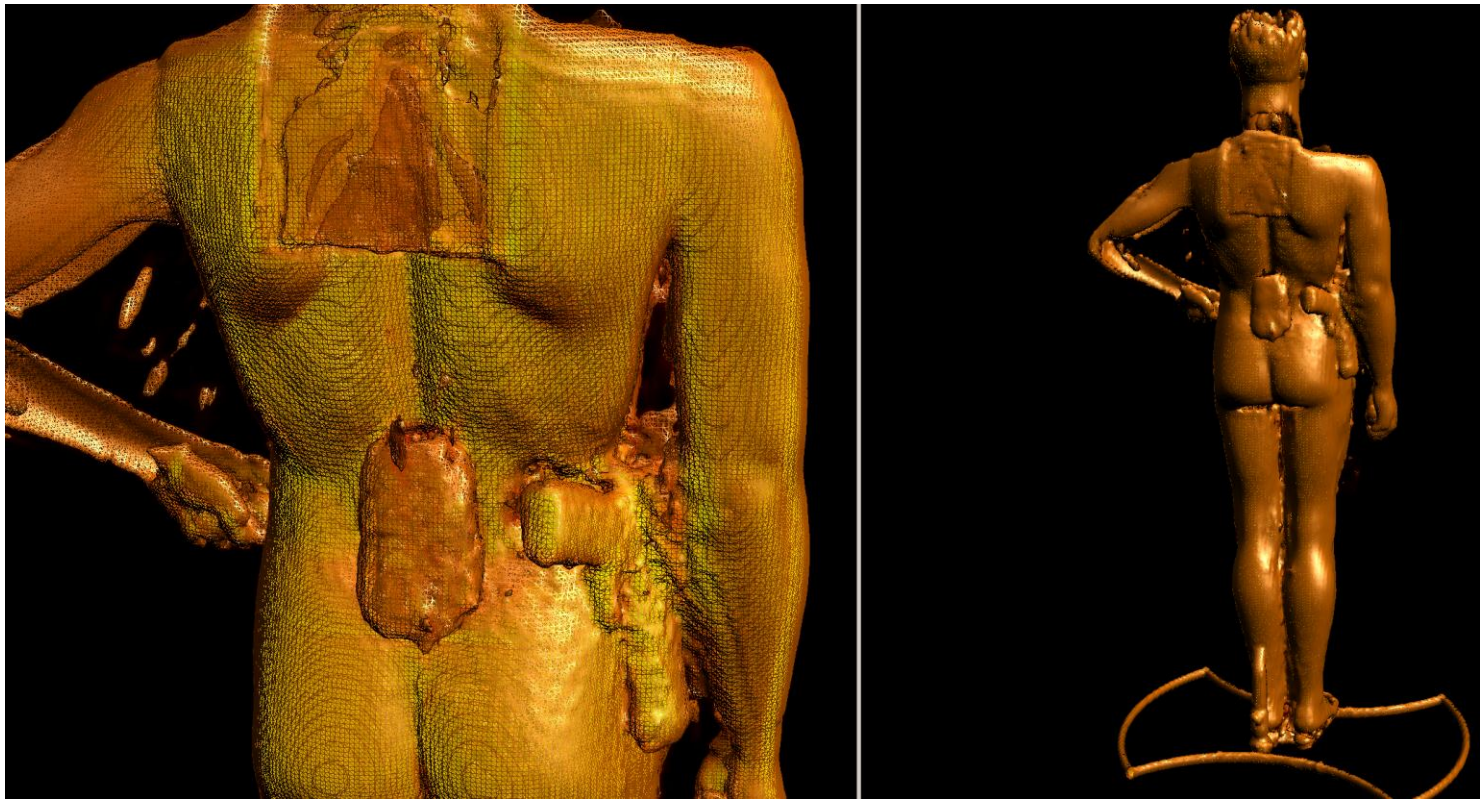
2. Extract Subset of Point Cloud for Surface

- Front and side views of 3-D point cloud
- Each voxel represents reflectivity value



3. Calculate Meshed Surface

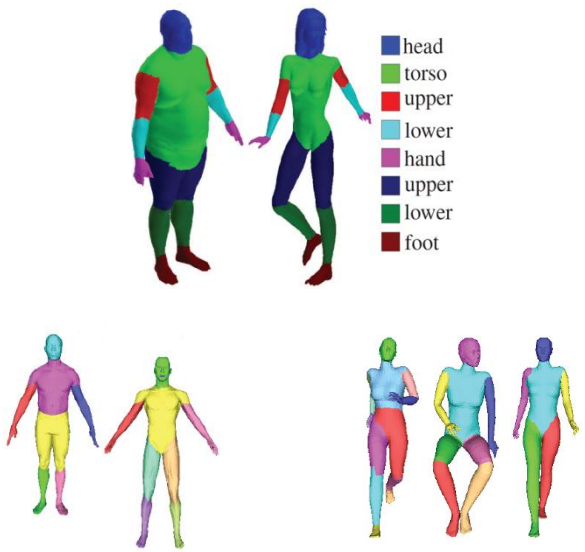
- Image rendered using VolRover
  - Volume visualization package developed in part by Chandrajit Bajaj at the Center for Computational Visualization at University of Texas



4. Segment Surface

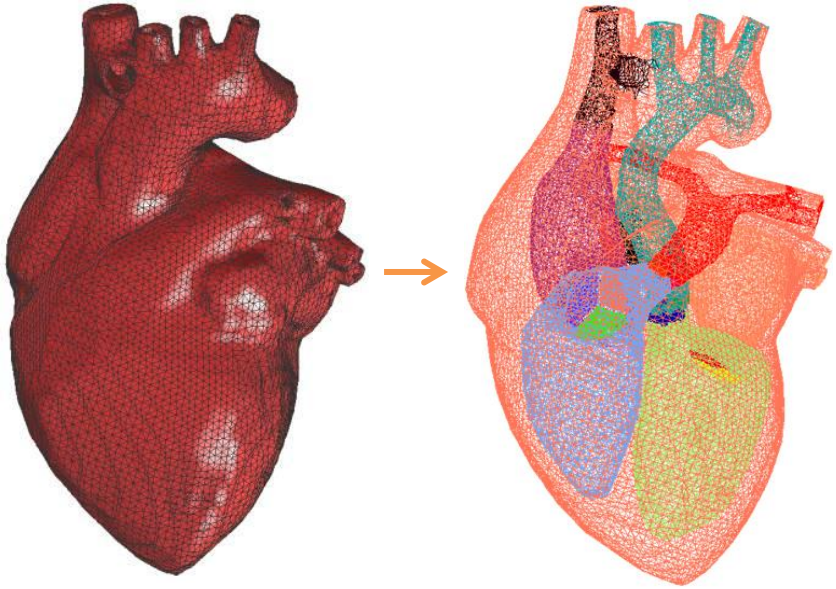
- Investigating multiple algorithms applied to other volumetric modalities

Conditional Random Fields



[1] Kalogerakis *et al*., Learning 3D Mesh Segmentation and Labeling, TOG 29(3), 2010
[2] Torralba,A., 2007. Sharing Visual Features for Multiclass and Multiview Object Detection.

Level-set Boundary Interior-Exterior Method (LBIE)



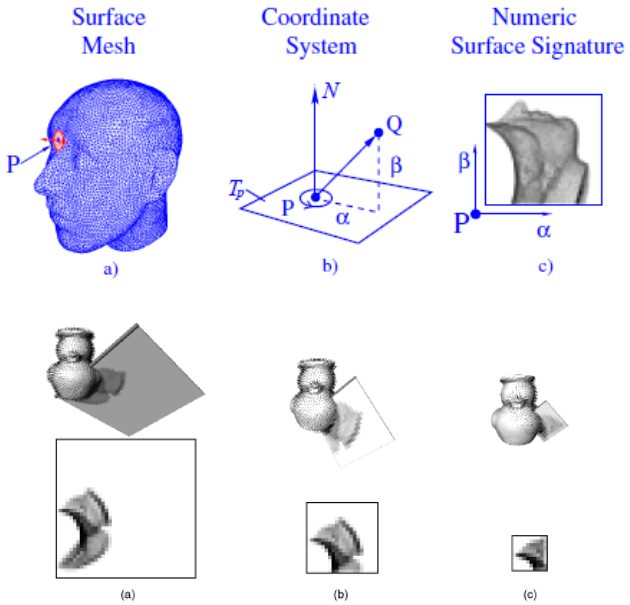
C. Bajaj, V.Pascucci, and D.Schikore

5. Feature Extraction

- Investigating multiple algorithms applied to other volumetric modalities

Spin Images

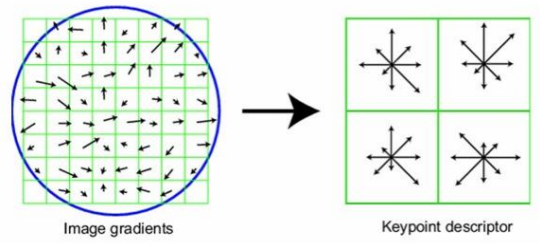
Algorithm used in range images which characterizes local surface curvatures.

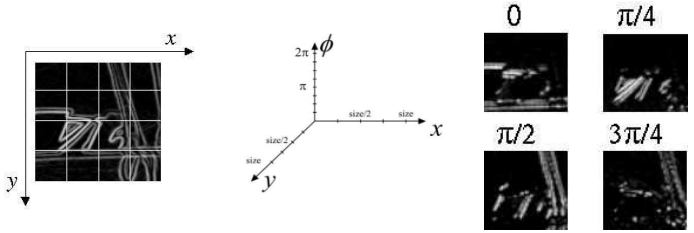


Johnson, A., Hebert, M., Using Spin Images for Efficient Object Recognition in Cluttered 3D Scenes

SIFT – (Scale Invariant Feature Transform)

Algorithm in computer vision which detects and describes local features.





Krystian Mikolajczyk, Cordelia Schmid, IEEE Transactions on Pattern Analysis & Machine Intelligence, Volume 27, Number 10 – 2005

Data Requirements: Case Categories

- Due to variance of anomaly types, algorithm development is focused on characterizing the human body.
- Scope of ATR dataset should be focused on a reduced subset of body types.

Outfits	2
1	single thin layer
2	second thicker layer
BMI	3
1	thin
2	average
3	large
Gender	2
1	female
2	male
Threat	5
1	none
2	large metal/dielectric
3	metal/dielectric (minmal threat)
4	knife
5	gun
Location	4
1	chest
2	back
3	legs
4	crotch

Data Requirements: Measurements

	# bodies	# Outfits	# Genders	# Threats	# Locations	# measurements / case	Time / measurement (minutes)	Total time / BMI case (hours)
BMI 1, male /female	10	2	2	5	4	3	2	80
BMI 2, male	50	2	1	5	4	3	2	200
BMI 2, female	10	2	1	5	4	3	2	40
BMI 3, male /female	10	2	2	5	4	3	2	80

Data Requirements: Cost

Total time / person (hours):
4
Total number of scans / person:
120
Total number of threat cases / outfit:
20

Cost / hour ($):
150
Total number of hours:
400
Total cost ($):
60,000

Conclusions

- Better data produces better algorithm performance
  - Enhanced coverage (viewing perspective)
  - Higher frequency (lateral resolution)
  - Wider bandwidth (range resolution)
  - Reduced clothing and multipath artifacts (clutter reduction)
- Focus is directed towards obtaining 3-D millimeter-wave image specific feature vectors
  - Better feature vectors will improve performance of classifiers
  - Three dimensional volumetric rendering reduced in dimensionality
- All methods are data-driven methods
  - Need to narrow scope to limited number of body types for initial development