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Automatic Characterization of Body-Borne Threats Using Wideband Radar

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Opportunity

In order to reduce pat-down rate at airport radar body scanners we need to discriminate benign objects, such as money belts and belt buckles, from prohibited items. An effective way to do this is to develop an automatic algorithm that can distinguish potentially hazardous foreign objects from the benign ones.

This research proposes a method which can automatically determine permittivity and thickness of body-borne objects by processing wideband radar images. The algorithm can be used to find explosive threats and rule out benign objects. Starting with a reconstructed millimeter-wave radar image of the body with an anomaly attached to it, we extract the nominal body contour using a seven-term Fourier series in circumferential angle, which predicts the body surface in the absence of the object. We then subtract the ideal body response from the image and define the amount of peak body displacement observed in the radar image (this displacement is caused by a signal retardation due to the presence of a weak dielectric object). This and the weak front surface reflection of the attached foreign object let us calculate the permittivity using:

$$\varepsilon_r = (1 + \frac{d'}{d})^2$$

Data or Results

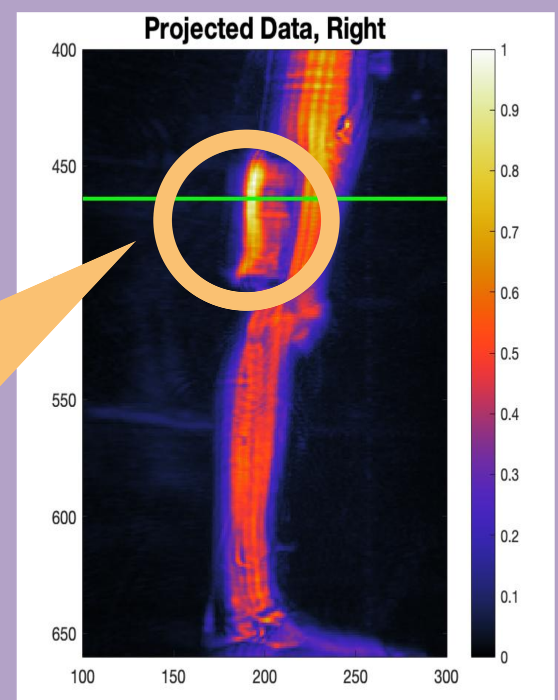
Using the proposed algorithm, the body displacement of d' = 1.6 cm and thickness of d = 3.6 cm was obtained. The permittivity of 2.09 was predicted for the body-borne object. The ground truth (a bag of petroleum jelly) for displacement, thickness and permittivity are 1.64 cm, 3.5 cm and 2.16 respectively.

The predicted permittivity for this case study is within 3 % of its ground truth and the thickness is calculated with an error of 0.1 cm which shows the automated algorithm works very well in this case.

This method can be used to separate threats from benign objects in the security screening of people, thus reducing the number of body pat-downs needed.

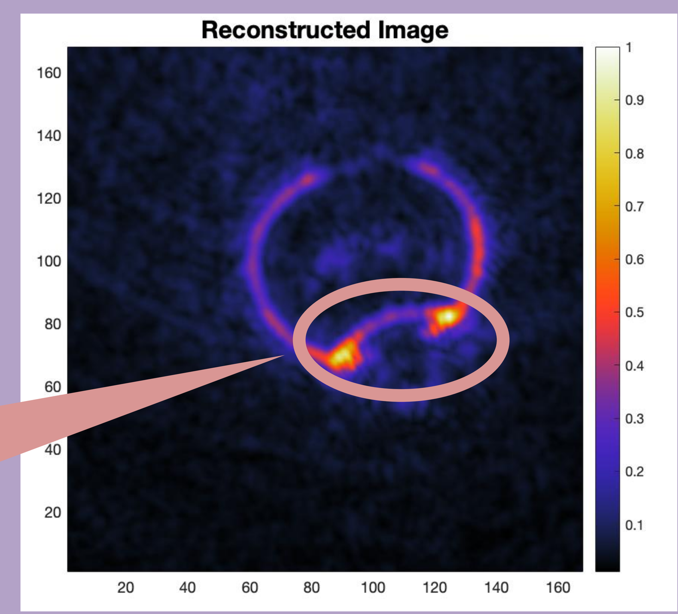
Approach

Step 1:
The Object, Scanner Image



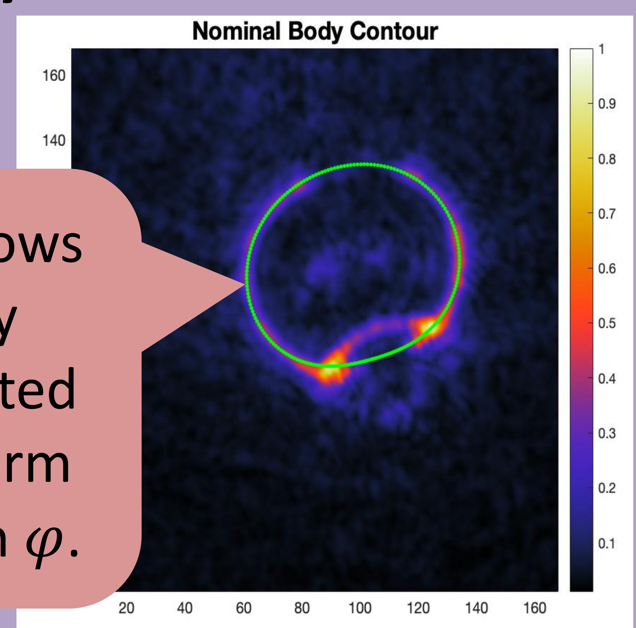
Petroleum Jelly attached to the lower right thigh.

Step 2:
Reconstructed 2D Cross Section Image



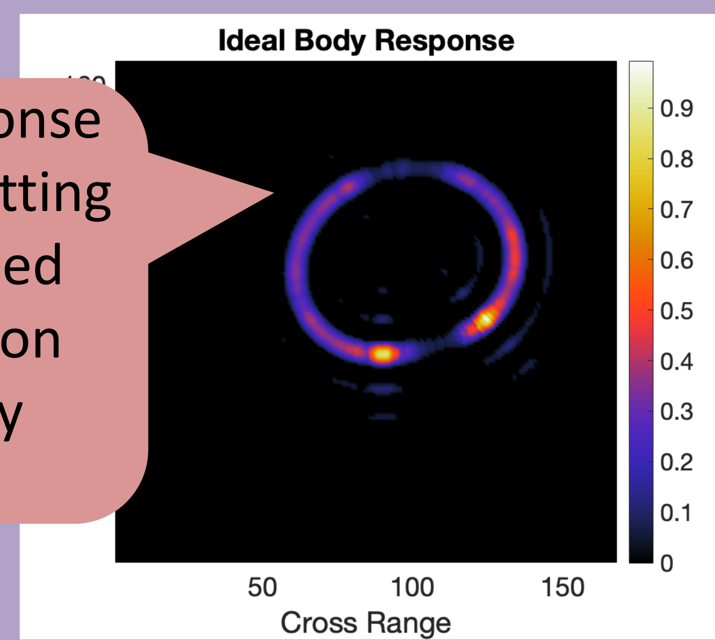
3.5 cm thick object is attached here!

Step 3:
Nominal Body Contour



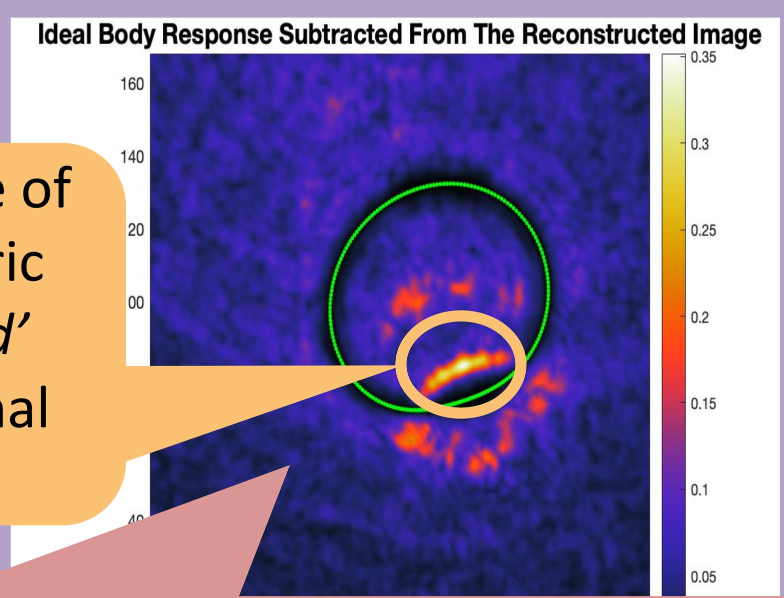
Green curve shows nominal body contour generated with a seven-term Fourier series in φ.

Step 4:
Ideal Body Response



Ideal body response generated by putting amplitude scaled sinc functions on nominal body contour

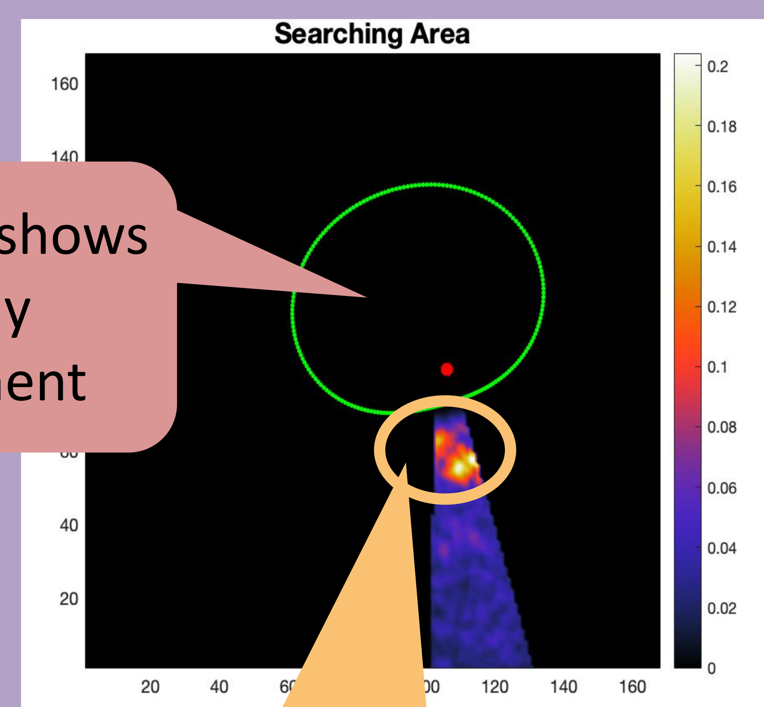
Step 5:
Finding the Peak Body Displacement



Back Surface of the dielectric displaced d' from nominal contour

By subtracting the ideal body response from the data, the displaced body pixels become dominant and can be found by thresholding the image.
Thresholds = 0.25, 0.4

Step 6:
Dielectric Thickness



The red dot shows the body displacement

Front Surface of dielectric extending d from nominal contour

Impact

The unique feature about my research is that it can find threats automatically. This addresses the problem of high false alarm rate in security checkpoints.

References

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3. B. Gonzalez-Valdes, Y. Alvarez, J. Martinez Lorenzo, F. Las- Heras, and C. Rappaport, "Sar processing for profile reconstruction and characterization of dielectric objects on the human body surface," *Progress In Electromagnetics Research*, vol. 138, pp. 269–282, 2013.
4. E. Wig, C. Rappaport, "Wideband Analysis of Imaging of Dielectric-Covered Curved Surfaces for Millimeter-Wave Security Scanning", unpublished.

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