Combined use of backscattered and transmitted images in X-ray personnel screening systems

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Abstract

Aviation security relies heavily on personnel screening using X-ray backscatter systems (XBS) or other advanced imaging technologies. Passenger privacy concerns and screening times can be reduced through the use of low-dose two-sided X-ray backscatter (Bx) systems, which can collect transmission (Tx) X-ray imagery without increasing dose. Bx images reveal objects placed on the body, such as contraband and security threats, as well as anatomical features such as bones and lung cavities. Bx image interpretation and segmentation algorithms can be guided by structures more clearly seen in Tx images. We demonstrate an approach that uses automatically extracted fiducial points on the body and localized active contour methods to segments lungs in acquired Tx and Bx images. Additionally, we derive metrics from the Tx image that can be related to the probability of observing internal body structure in the Bx image. Our results support the hypothesis that combining Tx and Bx data can lead to improved system performance.

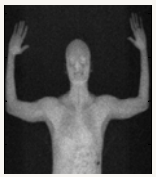
Relevance

There is a pressing need for reliable automated systems for analyzing whole-body scanner data. Because of millions of travelers pass through US airports every year, false alarm rates for these systems must be extremely low. Near-surface internal anatomical features, such as bones or lungs, can create high-contrast edges in Bx data that can generate false alarms. In previous work [1] we explored false alarm reduction for Bx images of the tibia; here we focus on false alarms generated by lung cavities. We fuse Tx and Bx data, which has been explored previously for luggage segmentation [3]. This provides on example of data fusion, a topic of interest to DHS. We anticipate that techniques for AIT false alarm reduction will be of great interest to vendors and to DHS explosives detection efforts.

Technical Approach

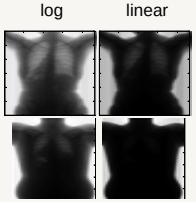
Problem Statement and Goals

- In thin (low-BMI) individuals, lungs are visible in Bx image, and may trigger false alarms.
- In newer systems, Tx is available as well. Can we use Tx to reduce false alarms?
- Fairly extensive dataset available from AS&E



Data observations

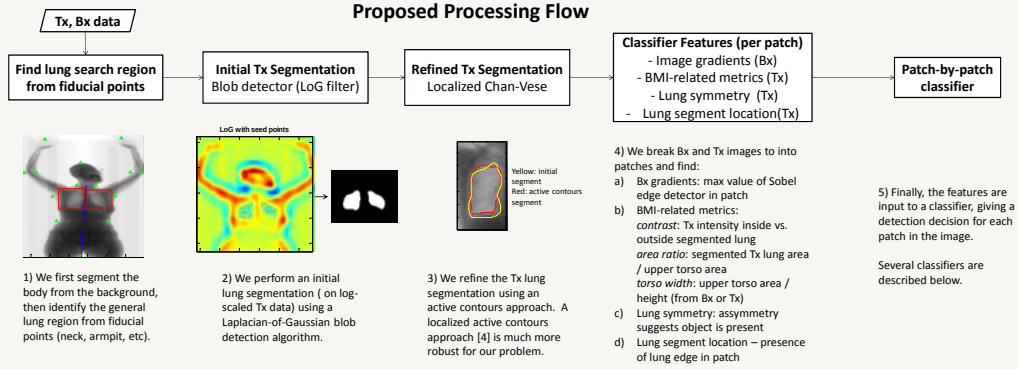
- Lung contrast is enhanced when Tx images viewed in log-scale, particularly in high-BMI subjects (see figure)
- Lungs are more clearly seen in Tx images; suggests Tx data should help identify lungs
- Lungs are much less visible in Bx data of high-BMI individuals; suggests BMI-related cues should be useful



Goals

- Our initial goal is to demonstrate that Tx-derived information can be used to reduce false alarms and improve performance
- We demonstrate this using standard classifiers; exploring more advanced machine learning tools is a future goal.

Proposed Processing Flow



1) We first segment the body from the background, then identify the general lung region from fiducial points (neck, armpit, etc).

2) We perform an initial lung segmentation (on log-scaled Tx data) using a Laplacian-of-Gaussian blob detection algorithm.

3) We refine the Tx lung segmentation using an active contours approach. A localized active contours approach [4] is much more robust for our problem.

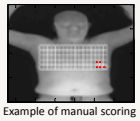
4) We break Bx and Tx images to into patches and find:

a) Bx gradients: max value of Sobel edge detector in patch
b) BMI-related metrics:
contrast: Tx intensity inside vs. outside segmented lung
area ratio: segmented Tx lung area / upper torso area
torso width: upper torso area / height (from Bx or Tx)
c) Lung symmetry: assymmetry suggests object is present
d) Lung segment location – presence of lung edge in patch

5) Finally, the features are input to a classifier, giving a detection decision for each patch in the image.

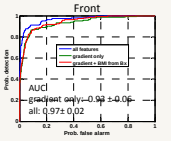
Several classifiers are described below.

Initial Results



Example of manual scoring

- For a set of 84 Tx/Bx images, we set up patches in lung region and manually noted patches with inclusions (i.e., objects on body surface)
- This gave162 patches with inclusions, and ~4800 front and ~3700 back patches without inclusions
- Extracted features were used to train two-class classifiers, using Weka 3.6 with 10-fold cross-validation
- Separate classifiers were trained for front and back



Results using Naïve Bayes classifier

- Assumes features are independent; not optimal but still gives reasonable performance, largely due to BMI metrics
- Blue line shows improvement due to Tx segmentation; benefit seen for both front and back data.

Metrics used	AUC, front	AUC, back
Bx gradient	0.86	0.91
Bx gradient, lung area, lung symmetry	0.981	0.983
Bx gradient, lung area, lung symmetry, lung edge location	0.985	0.994

Results using AdaBoost with J48 tree classifier

- Unlike N.B. classifier, this classifier is able to exploit dependencies between features (i.e. low BMI individual, high Bx gradient, lung edge in patch suggests edge is due to lung)
- Knowledge of lung segment location helps, but BMI metrics still most important

Accomplishments Through Current Year

- During the current year, we focused on reducing false alarms due to lung cavities through Tx/Bx fusion.
- Contrast enhancement was demonstrated for Tx images via logarithmic scaling, and an approach for lung segmentation was developed for Tx images.
- For example classifiers, Tx-derived metrics were shown to improve detection performance.
- Estimates of the passenger's BMI were found to be useful cues for reducing false alarms.

Future Work

- Joint Tx/Bx segmentation will be explored, vs. the current approach in which segmentation is sequential (Tx results used to guide Bx)
- Machine learning tools that combine features across nearby patches will be investigated.
- Potentially, Tx images can be used to reduce false alarms due to other features (spine, other bones).

Opportunities for Transition to Customer

- Direct transition to commercial partner is possible; algorithm code developed by Tufts University has been provided to AS&E for assessment.
- Results are being provided to the general DHS community for AIT improvement

Patent Submissions

- IP has been disclosed to the Tufts University Office for Technology Licensing and Industry Collaboration.
- IP assessment is currently underway.

Publications Acknowledging DHS Support

[1] C. Allen and E. Miller, "Anomaly detection in X-ray backscatter leg images using training data," Gordon Research Conference: Detecting Illicit Substances, June 26-July 1, 2011, Luca (Barga), Italy.

[2] "Combined use of backscattered and transmitted images in X-ray personnel screening systems" (current authors) has been submitted to SPIE Defense, Sensing and Security Conference, April 2012, Baltimore, MD.

Other References

[3] O. Feron and A. Mohammad-Djafariy, "Image fusion and unsupervised joint segmentation using a HMM and MCMC algorithms", Journal of Electronic Imaging, vol. 14, no. 2, pp. 1–12, 2005.

[4] S. Lankton and A. Tannenbaum, "Localizing region-based active contours," IEEE Trans. on Image Processing, Vol. 17(11), November 2008.

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