**Issue:** Automatic detection of threat items in 3D baggage security imagery poses a volumetric object class recognition problem.

**Approach:** 3D features are isolated from segmented volume regions to form the input to an automated classification approach.

Dual Energy Computed Tomography (CT) scanners, currently available for explosive material detection, can also produce 3D volumetric imagery of baggage items suitable for image analysis and recognition. This 3D imagery does not suffer from the occlusion problems associated with 2D X-ray screening.

### Feature Extraction & Classification

Complex baggage volumes are segmented using [1]. For each segmented "object" Histogram of Space Index (HSI) [2] and 3D Zernike (3DZ) shape descriptors are computed [3].

HSI captures the distribution of curvature classes, shape index $SI$, for each point, $p$, on the surface of the segmented object based on the principle curvatures, $k_1, k_2$.

$$SI(p) = \frac{1}{2} \left( 1 - \frac{\tan^{-1}(k_1(p)/k_2(p))}{\pi} \right)$$

3DZ shape descriptors use a set of complex orthogonal basis functions (3D moments, $\Omega$) defined over a unit sphere. 3D projection to this sphere in voxel-space produces a descriptor, $F_n l$, of moment coefficients [3].

$$t_{nl} = \frac{3}{4\pi} \sum_{r=0}^{\infty} \frac{\Gamma(r+1)}{\Gamma(r+3/2)} M_{nr} r^{r+1/2}$$

Combined HSI+3DZ feature vectors describe the +ve & -ve examples used for classifier training.

### Results

<table>
<thead>
<tr>
<th>Method</th>
<th>Accuracy (%)</th>
<th>Precision (%)</th>
<th>TNR (%)</th>
<th>Recall (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decision Tree</td>
<td>98.41</td>
<td>100</td>
<td>100</td>
<td>96.72</td>
</tr>
<tr>
<td>Neural Network</td>
<td>97.61</td>
<td>100</td>
<td>100</td>
<td>95.08</td>
</tr>
<tr>
<td>Boosted Trees</td>
<td>98.41</td>
<td>100</td>
<td>100</td>
<td>96.72</td>
</tr>
<tr>
<td>SVM</td>
<td>98.41</td>
<td>96.72</td>
<td>97.01</td>
<td>100</td>
</tr>
<tr>
<td>Random Forest</td>
<td>98.41</td>
<td>100</td>
<td>100</td>
<td>96.72</td>
</tr>
</tbody>
</table>

Stability is consistent with high accuracy and low TNR using either HSI features only or HSI+Z3D.

Future work will explore performance over larger data sets comprising and improvements in initial segmentation.

---

There are clear deficiencies in 2D X-ray imaging if the threat item is poorly orientated (above).

Dual Energy Computed Tomography (CT) scanners (above left), currently available for explosive material detection, can also produce 3D volumetric imagery of baggage items suitable for image analysis and recognition. This 3D imagery does not suffer from the occlusion problems associated with 2D X-ray screening.

Despite reliance on (noisy) surface curvature, HSI features are maximally discriminative over Z3D features on this task supporting [1].

A range of 3D objects are detected based on a multilayer architecture of filter responses, mapped through $N_p$ a priori discriminative voxel features [4].

Prior work has investigated isolated complex object detection (striped down firearm) using 3D SIFT points matching [3].

In addition, we have considered a visual cortex based hierarchy of processed filter responses forming the input to a Support Vector Machine (SVM) classifier [4].

Results over varying classification approaches (Z3D features only)

Method | Accuracy (%) | Precision (%) | TNR (%) | Recall (%)
---|---|---|---|---
Decision Tree | 70.63 | 81.58 | 89.23 | 50.82
Neural Network | 80.95 | 91.11 | 93.85 | 67.21
Boosted Trees | 89.68 | 92.86 | 93.85 | 85.25
SVM | 93.65 | 88.52 | 90.14 | 98.18
Random Forest | 93.02 | 95.38 | 95.38 | 85.57

Results over varying classification approaches (HSI features only)

Method | Accuracy (%) | Precision (%) | TNR (%) | Recall (%)
---|---|---|---|---
Decision Tree | 98.41 | 100 | 96.72 | 96.72
Neural Network | 89.68 | 96.15 | 96.9 | 81.97
Boosted Trees | 98.41 | 96.72 | 97.01 | 100
SVM | 98.41 | 96.72 | 97.01 | 100
Random Forest | 100 | 100 | 100 | 100


Successful “bottle” object class detection in cluttered imagery

Successful “bottle” object class detection in cluttered imagery

A comparison of classification approaches for threat detection in CT based baggage screening

Results

Background: CT Security Scanning

An example bag containing... a harmless item?... or a serious threat?

Related Work

No slide (barrel) fitted

No magazine loaded

(a) Pistol frame reference (b) Correct location identified via 3D SIFT

There are clear deficiencies in 2D X-ray imaging if the threat item is poorly orientated (above).