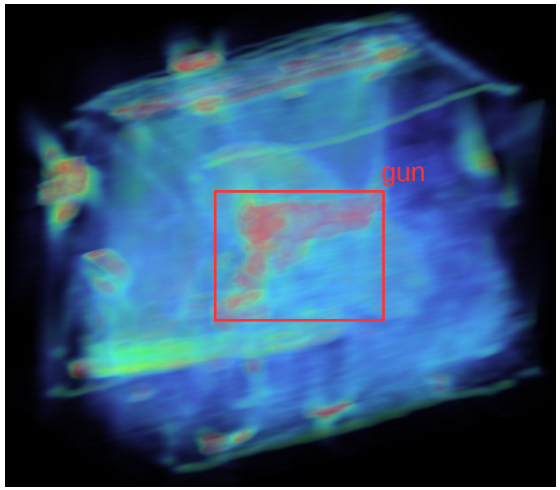
Automatic Object Classification for 2D X-ray and 3D CT

“in defence of shape based detection”



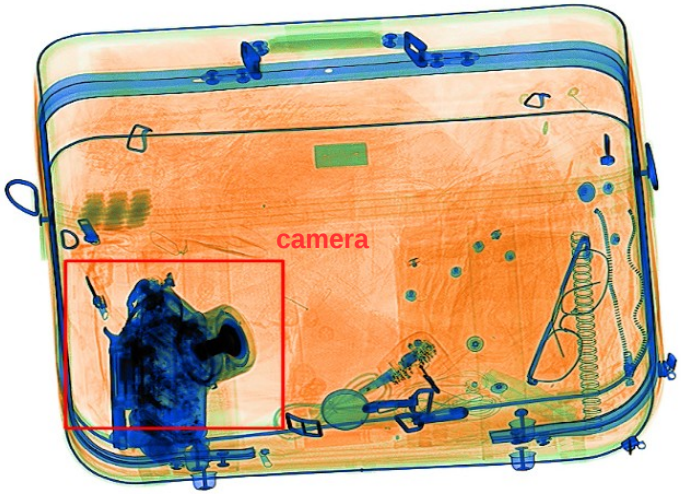


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Image sources: public domain (fair use) + published research output [Slide S:16]

What / How / Why ?

- **Baggage Inspection** (carry on and hold)
- Automatic **threat item detection (guns / knives)**
- **Automatic object classification algorithms**
- **Potential Impact:**
  - software enhancement (“add-on”) to existing X-ray or 3D CT hardware
  - high detection rates / low false positive
  - objects and parts of objects (dis-assembled)
  - augment existing screening capability / extend screening foot-print (buildings / postal / customs / prisions)

~98%+, < 1 sec., FP <1%, invariant

Concept of Operation

?

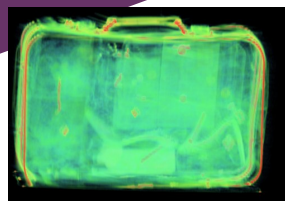
- Complex / Cluttered ?
- Target items ?
- “bulk” items ?

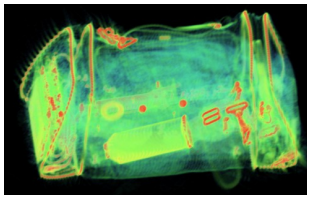
EDS

Operative Review

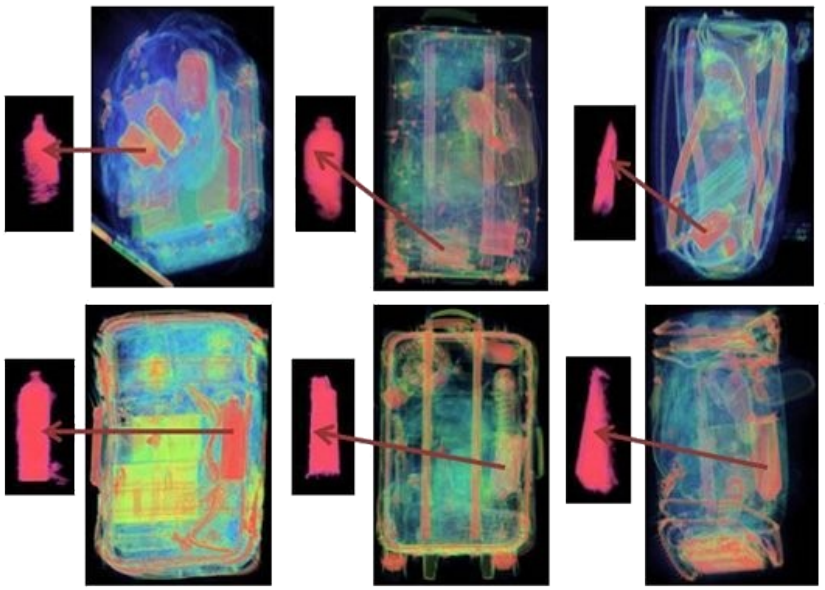
Image sources: public domain (fair use) + published research output [Slide S:16]

Our research ...

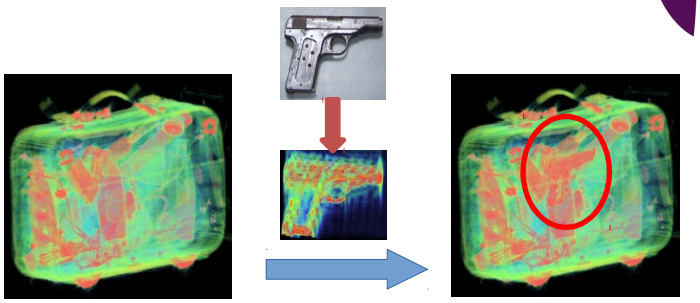




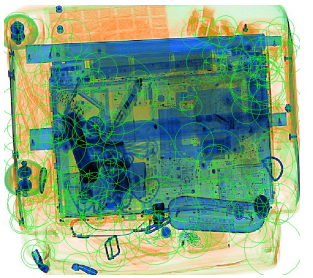
[Megherbi / Breckon et al. '10]



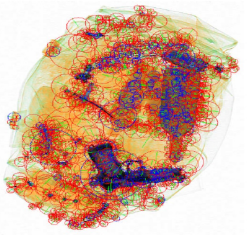
[Megherbi / Breckon et al. '12]

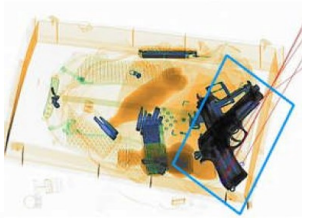


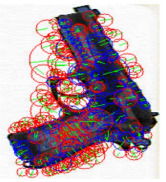
[Megherbi / Breckon '12]

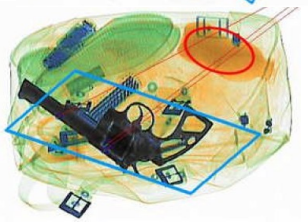


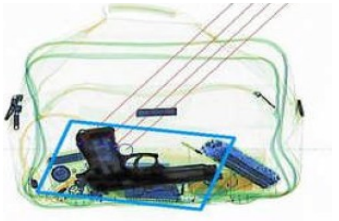
[Deveraux / Breckon '16]











[Turscany / Breckon '13]

- Dual Energy CT imaging (**3D shape + materials**)
  - object detection & classification
  - segmentation
  - threat image projection
- **2D X-ray** imaging
  - complexity analysis
  - object detection

Working with:

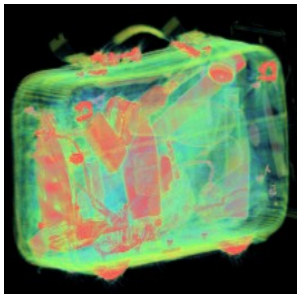
CPNI Centre for the Protection of National Infrastructure | dstl | REVEAL | Department for Transport | Metropolitan Police | Home Office Scientific Development Branch

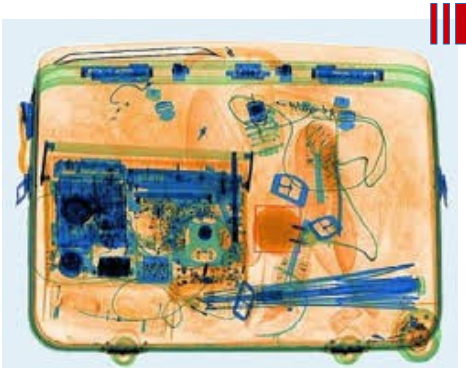
….. towards **total baggage/parcel understanding**

Image sources: public domain (fair use) + published research output [Slide S:16]

High Level *overview*

3D CT





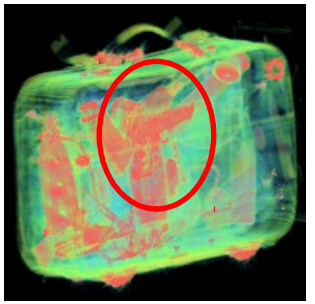
2D X-ray

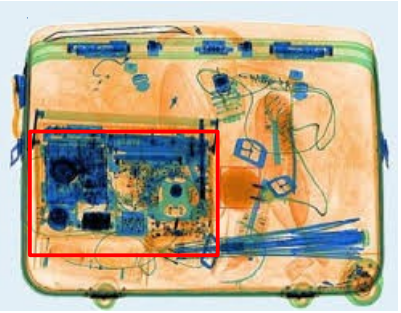
Image

Invariant Feature Representation

Detection & Classification

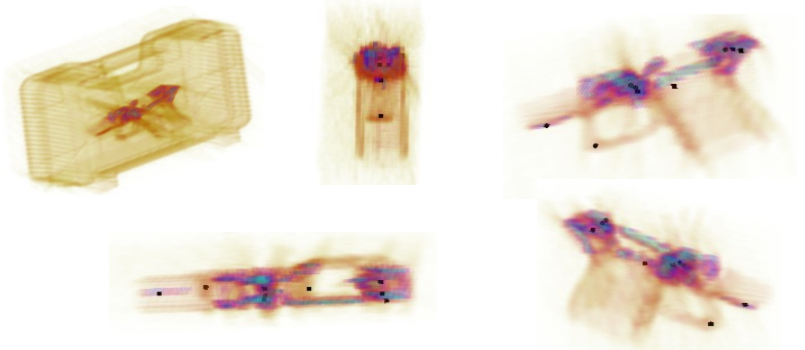
(via machine learning)

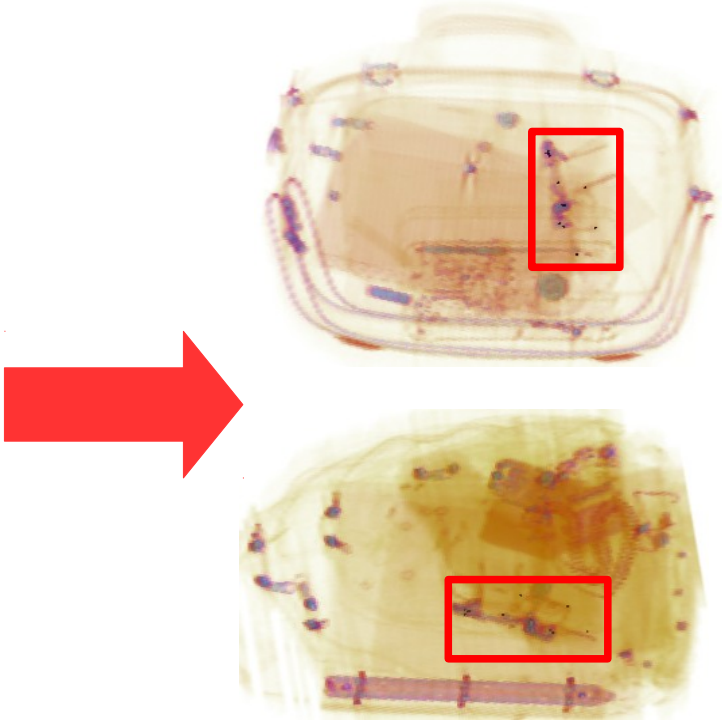




Understanding

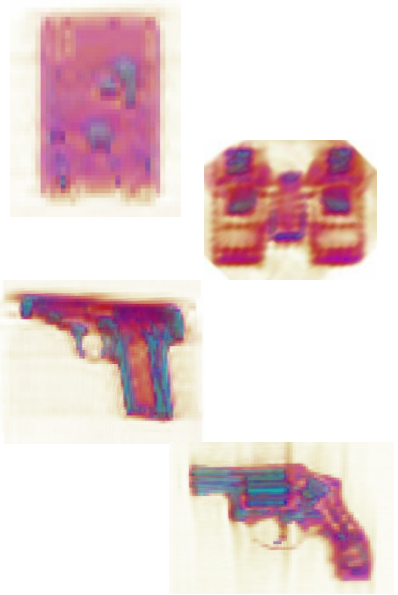
Object Detection & Classification in 3D CT

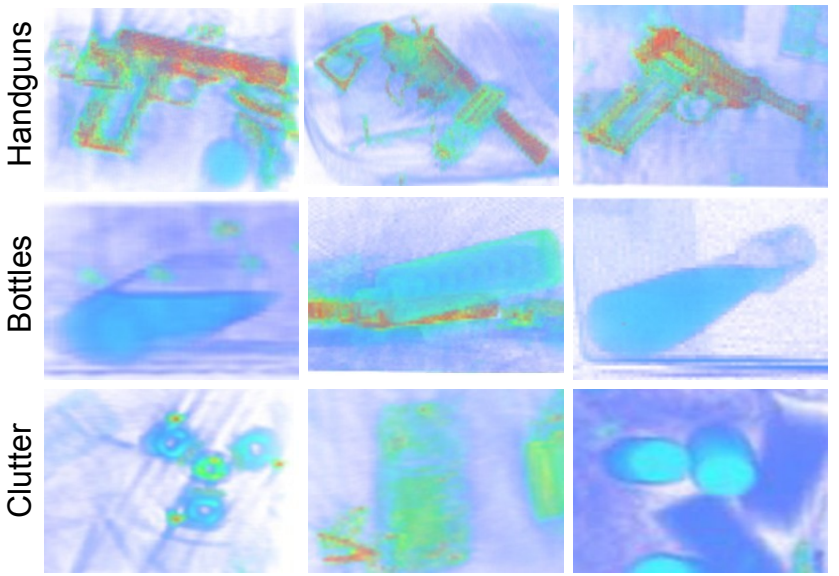




Single signature feature-point based **detection**: ~90% detection

[Flitton, Breckon, Megherbi - 2010]





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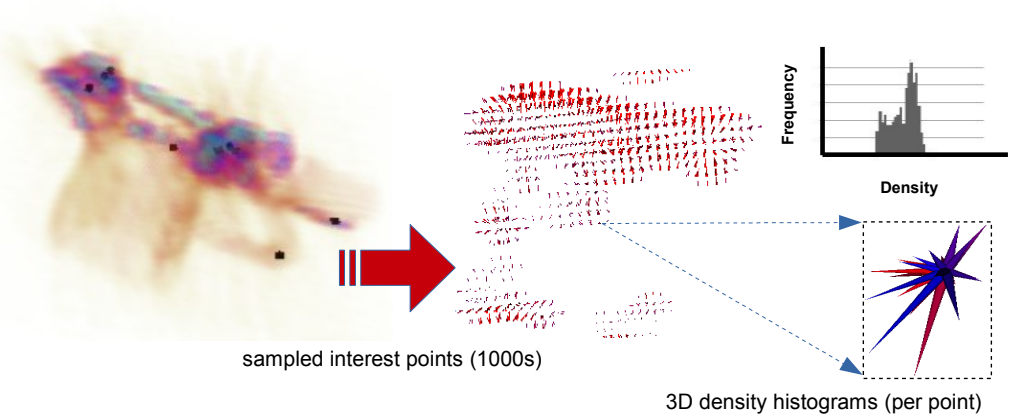
"bag of visual words" generalized signature **classification** : ~98+% detection, low FP (<1%)

[Mouton, Breckon, 2014] [Mouton, Breckon 2015] [Flitton, Breckon 2015] [Flitton, Breckon 2012]

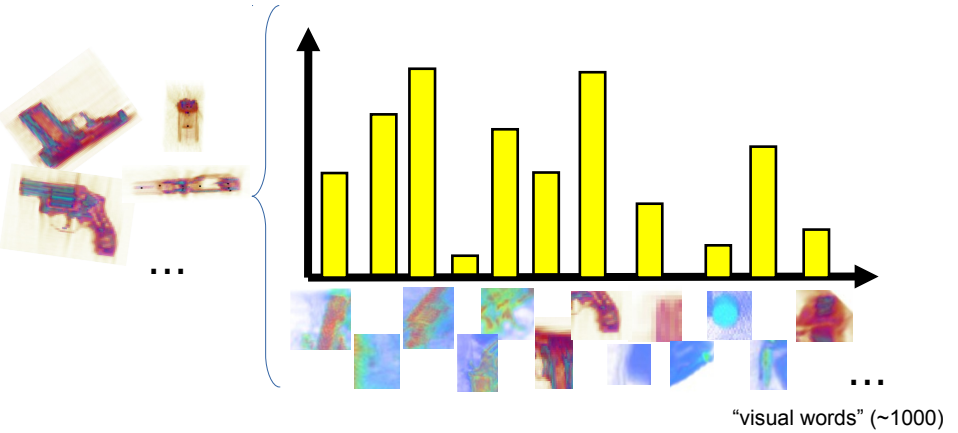
Image sources: public domain (fair use) + published research output [Slide S:16]

Some technical insight ….

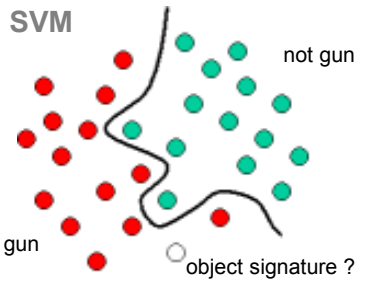
- **key-point** descriptors [video]

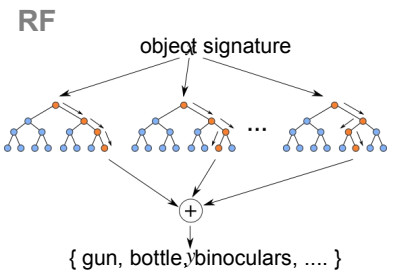


- **“bag of visual words” signature**
  - each object type represented as histogram of visual word occurrence



- **Machine Learning Classification:**
  - Support Vector Machine (SVM)
  - Random Forests (RF)

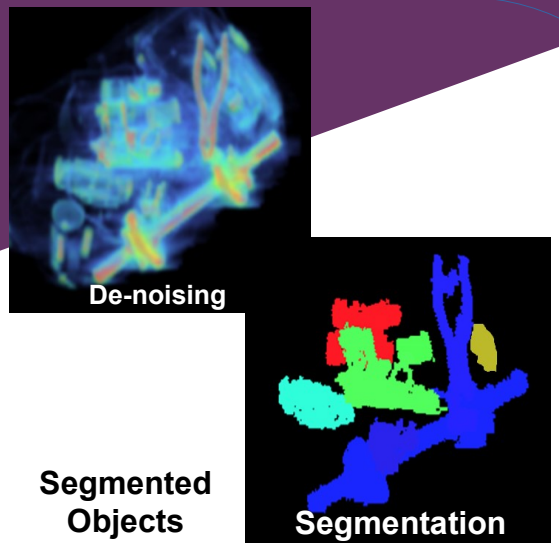




- Strongly **invariant: rotation**, **scale**, object {**occlusion | disassembly**}

Image sources: public domain (fair use) + published research output [Slide S:16]

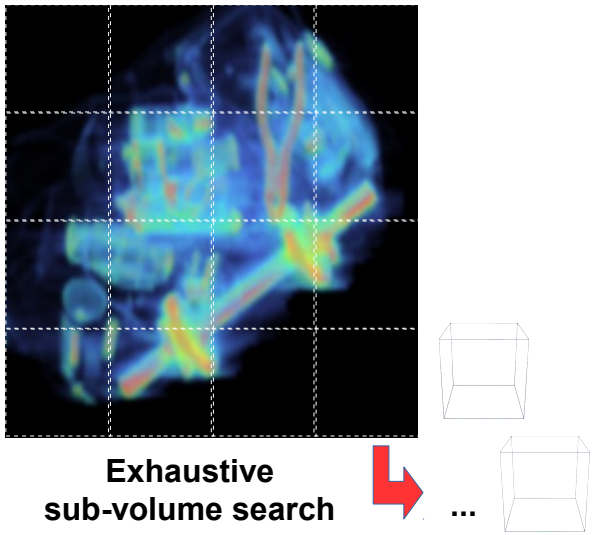
… which feeds back to object detection



Segmented Objects

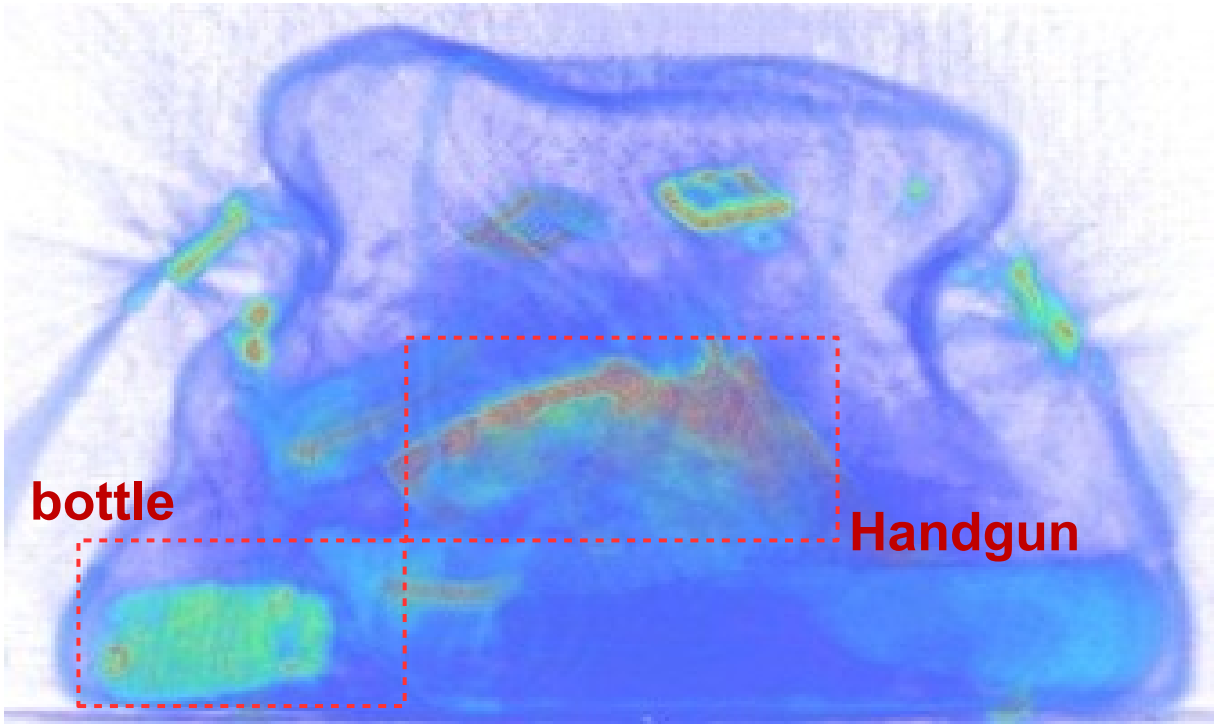
[Mouton, Breckon 2015]

Or:



Exhaustive sub-volume search

...

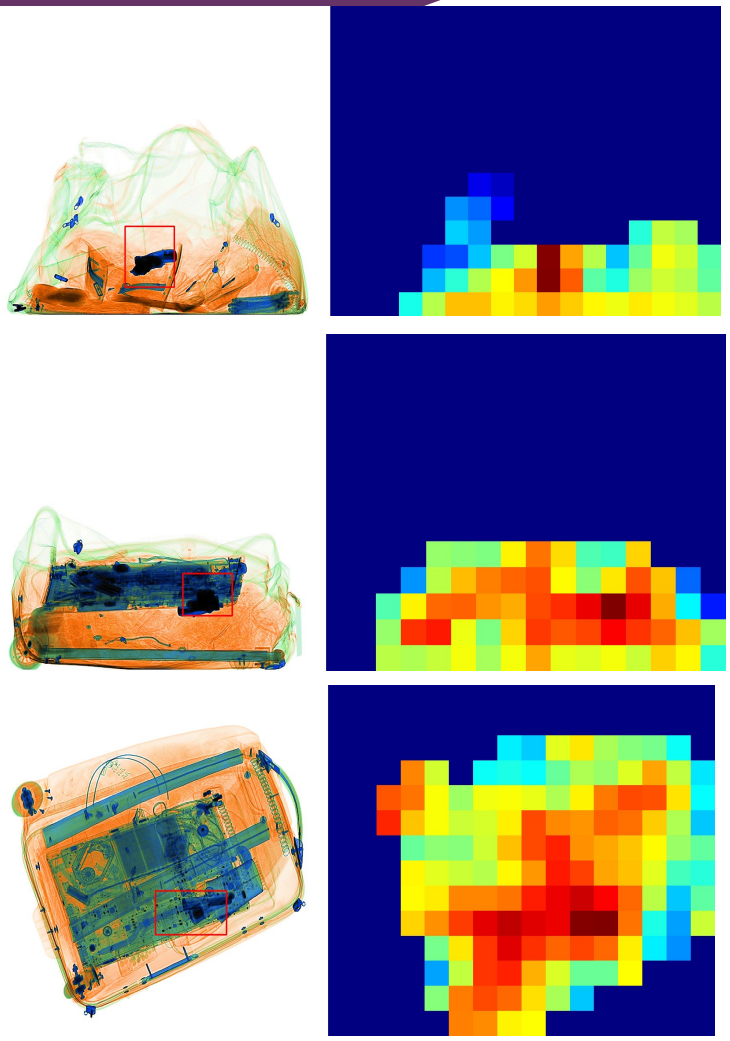


resolution 1.56 x 1.61 x 5 (mm)

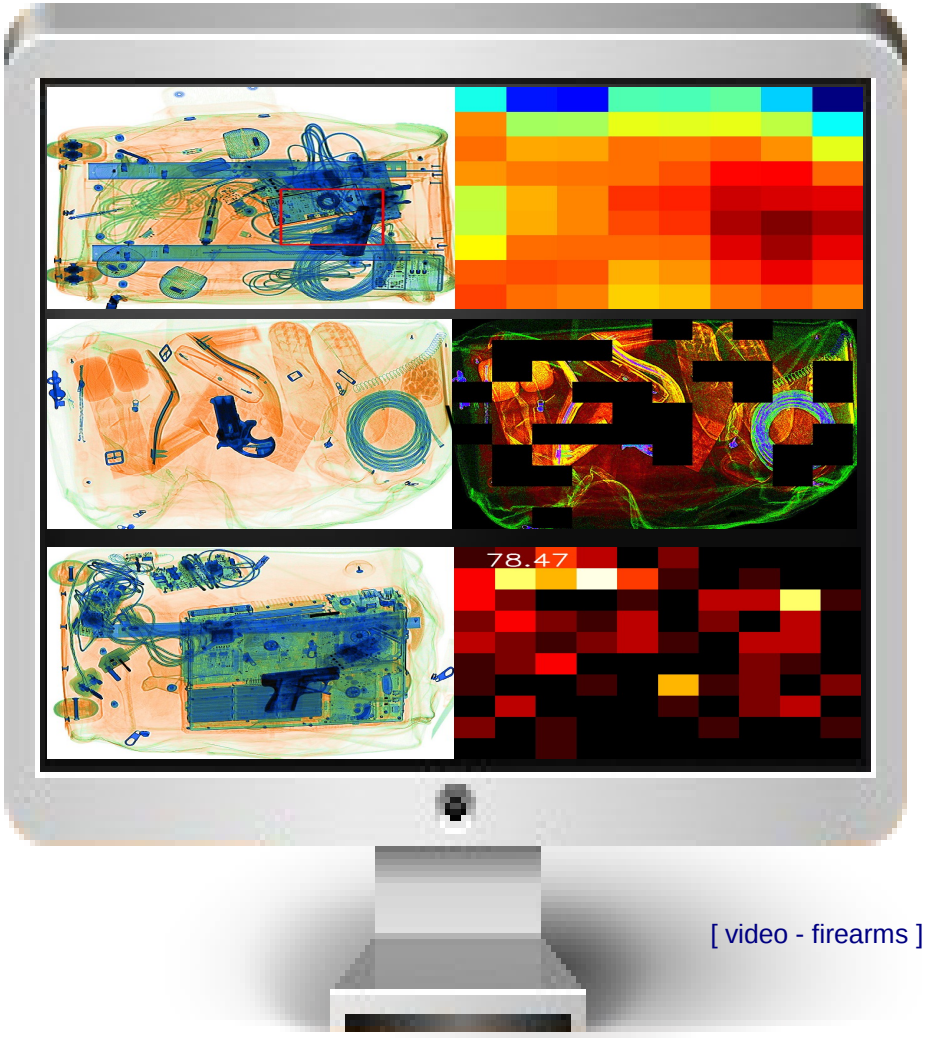
Method	Class	True +	False +	Prec.
[Mouton, Breckon, 2014]	Handgun	99.71	0.28	0.990
	Bottle	98.88	0.60	0.987

Image sources: published research output [Slide S:16]

Detection & classification in 2D X-ray



[virtual baggage machine]



[video - firearms]

Image sources: published research output [Slide S:16]

Method	Class	True +	False +	Prec.
[Turcsany et al. 2013]	Gun	99.07	4.31	0.990
[Akcay et al. 2016]	Gun	85.81	11.76	0.980

Working with:

“Bag of Visual Words” Pipeline

[in 2D X-ray]

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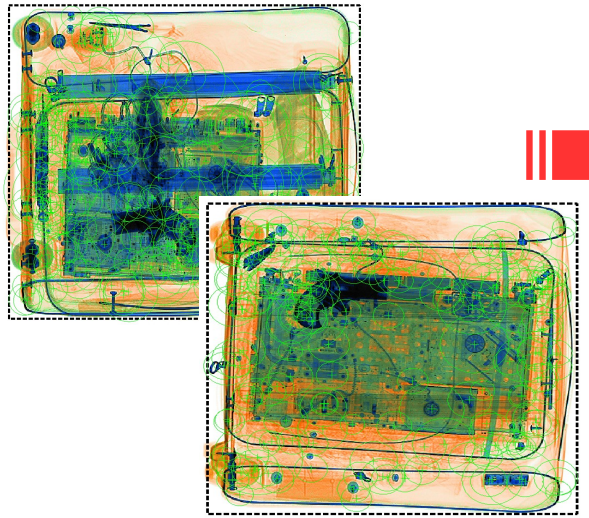
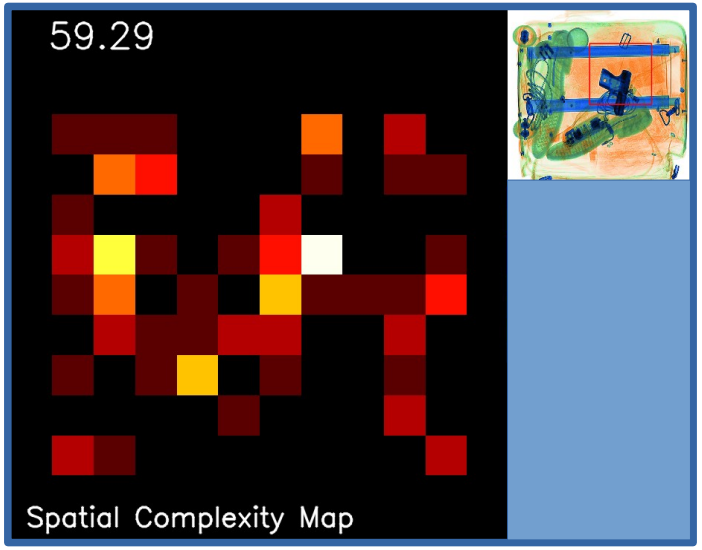


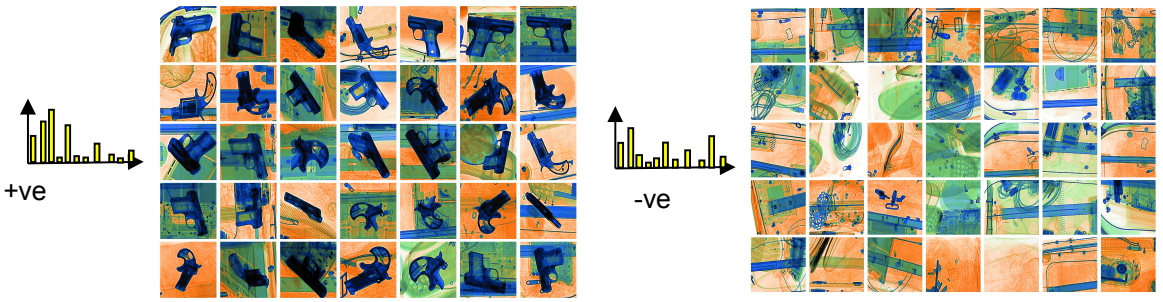


key-point descriptors

(complexity assessment for free)

[video - complexity]

“bag of visual words” signature



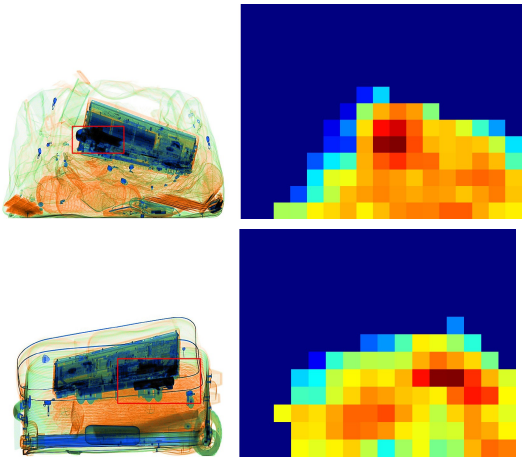


Image sources: published research output [Slide S:16]

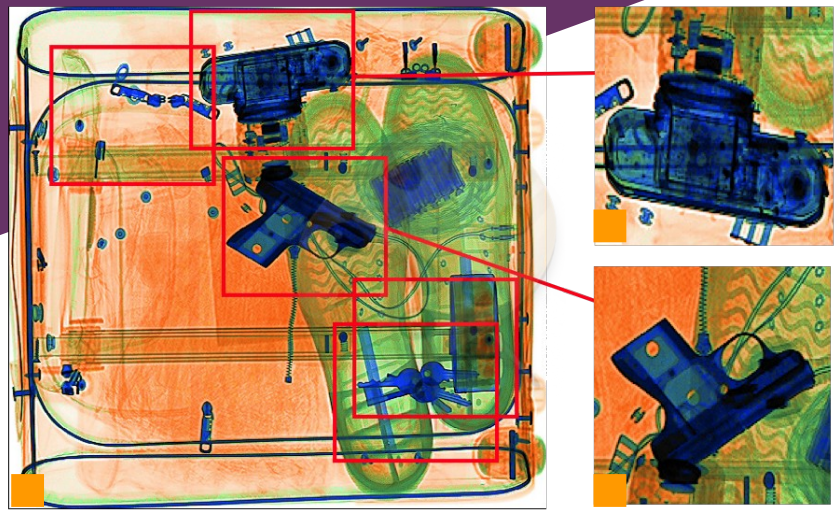
SVM **Classification**

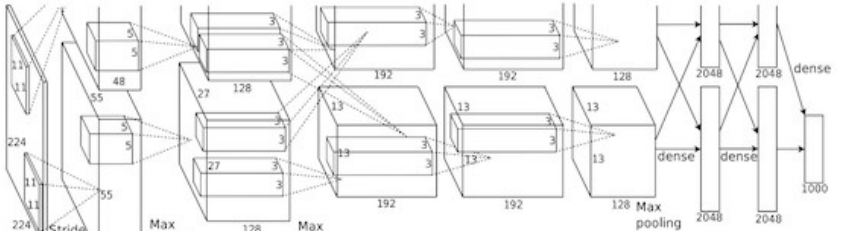
[video - vbm]

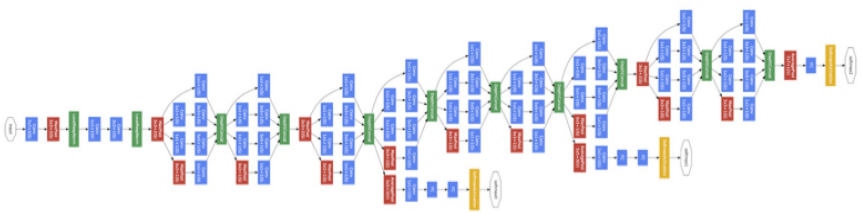
[Turcsany, Mouton, Breckon 2013] [Akcay, Kundegorski, Devereux, Breckon 2016]

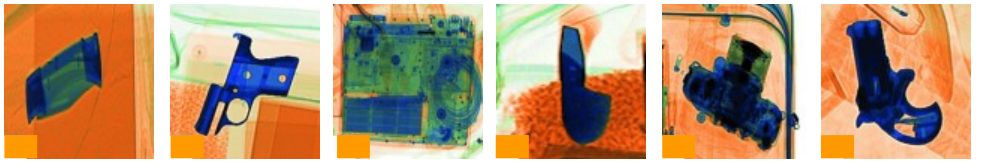
Latest Research

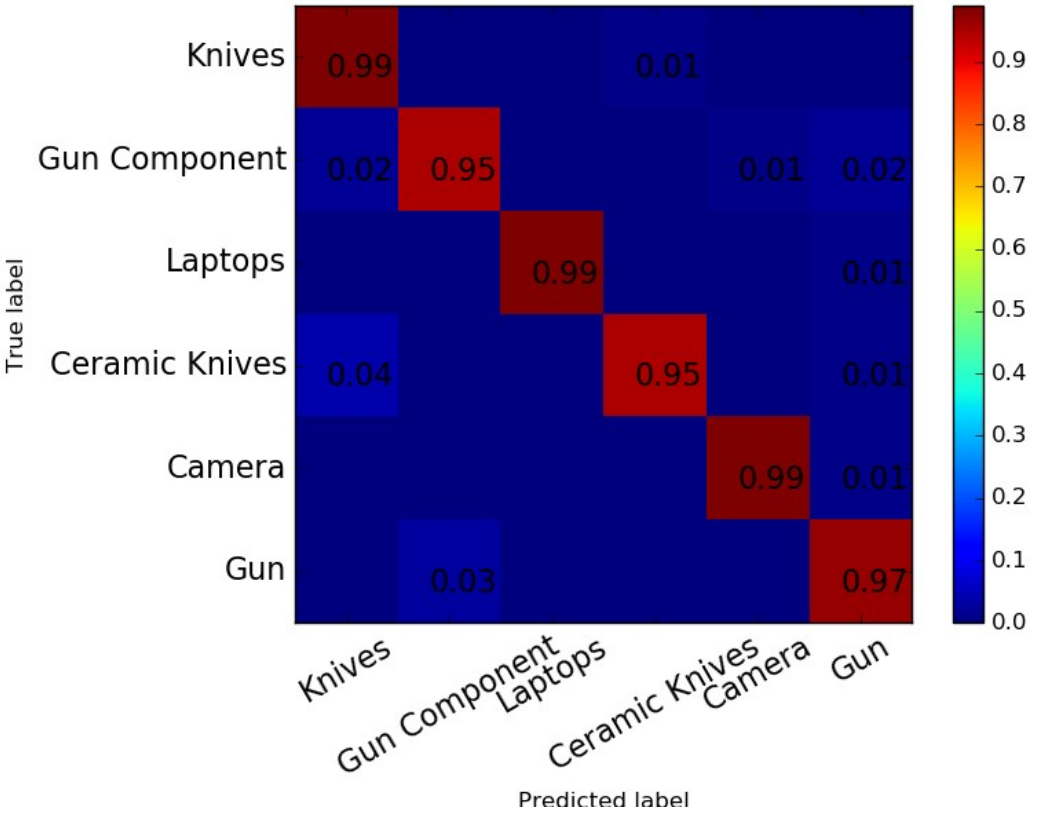
[in 2D X-ray] ...











Method	Class	True +	False +	Prec.
[Akcay et al. 2016]	Gun	98.62	0.21	0.990

- Deep Convolutional Neural Network : Features → Classification (end to end)
  - **95% (True+) over 6 object categories**

Working with:

Home Office

[Akcay, Kundegorski, Devereux, Breckon 2016]

Image sources: published research output [Slide S:16]

Experience in the Field ...

Image sources: public domain (fair use) published research output [Slide S:16]

- **Data access:**
  - Reveal CT80 data + various 2D X-ray (via UK government)
  - data file formats: VTK/ITK, DICOM or “obvious to the experienced hacker”
  - 2D X-ray formats : standard but compressed

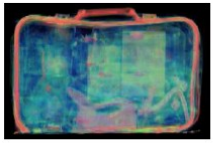
[video]
[video] #2

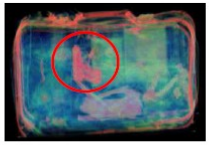
- **Entry into field:** open UK Home Office call (2007)
  - Today: 8 years, 4 projects and 17+ publications later

HM Government

- **Publications:** “never unreasonably withheld”
  - published in top conference / journal venues
  - wider impact in generalized 3D recognition + medical CT

- **Algorithm Deployment:** 3D TIP solution





Space of future research ….

(and where we are now)

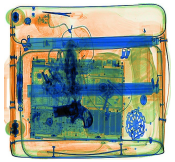
Image sources: published research output [Slide S:16]

Performance (accuracy)
- how well do we perform threat object detection ?

98-99%+ve / 4% -ve

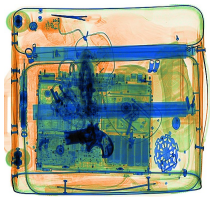
[Akcay, Kundegorski,
Devereux, Breckon 2016]

Speed (real-time ?)
- how fast do we perform threat object detection ?



2D X-ray : < 1 sec.
3D CT : single CPU / non-parrallel / no GPU **= ~minutes**

e.g. [Akcay, Kundegorski,Devereux, Breckon 2016] [Mouton / Breckon, 2014]



SWaP (Size,Weight & Power) / ***C****ost*
- the engineering cost of
"performing threat object detection" ?

2D X-ray : regular PC
3D CT : high end workstation

Latest Technical Publications

2D X-ray Detection (hot off the press):
Transfer Learning Using Convolutional Neural Networks For Object Classification Within X-Ray Baggage Security Imagery (S. Akcay, M.E. Kundegorski, M. Devereux, T.P. Breckon), In Proc. International Conference on Image Processing, IEEE, 2016. (to appear)

2D X-ray Detection: Improving Feature-based Object Recognition for X-ray Baggage Security Screening using Primed Visual Words (D. Turcsany, A. Mouton, T.P. Breckon), In Proc. International Conference on Industrial Technology, IEEE, pp. 1140-1145, 2013.

3D CT Segmentation:
Materials-Based 3D Segmentation of Unknown Objects from Dual-Energy Computed Tomography Imagery in Baggage Security Screening (A. Mouton, T.P. Breckon), In Pattern Recognition, Elsevier, Volume 48, No. 6, pp. 1961–1978, 2015.

3D CT Overview:A Review of Automated Image Understanding within 3D Baggage Computed Tomography Security Screening (A. Mouton, T.P. Breckon), In Journal of X-Ray Science and Technology, IOS Press, Volume 23, No. 5, pp. 531-555, 2015.

3D CT Detection: Object Classification in 3D Baggage Security Computed Tomography Imagery using Visual Codebooks (G.T. Flitton, A. Mouton, T.P. Breckon), In Pattern Recognition, Elsevier, Volume 48, No. 8, pp. 2489–2499, 2015.

3D CT Detection: 3D Object Classification in Baggage Computed Tomography Imagery using Randomised Clustering Forests (A. Mouton, T.P. Breckon, G.T. Flitton, N. Megherbi), In Proc. International Conference on Image Processing, IEEE, pp. 5202-5206, 2014

3D CT TIP: Fully Automatic 3D Threat Image Projection: Application to Densely Cluttered 3D Computed Tomography Baggage Images (N. Megherbi, T.P. Breckon, G.T. Flitton, A. Mouton), In Proc. International Conference on Image Processing Theory, Tools and Applications, IEEE, pp. 153-159, 2012.

Durham University

All available open access - full listing including all other references.