Statement of Work
Third Party Algorithm Development and Evaluation of Detection of Liquid Explosives in Dual-Energy Digital Radiographic/TIP Ready X-ray Images - Public Version

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1. Summary

The purpose of this statement of work is for third party collaborators to train, validate and have Lawrence Livermore National Security, LLC (LLNS) evaluate algorithms to detect liquid threats in digital radiography (DR)/TIP[1] Ready X-ray (TRX) images that will be provided by LLNS through the Transportation and Security Administration (TSA). LLNS will provide a set of images with threat(s) to determine detection rates and non-threat images from airports to determine false alarm rates. A key including a bounding box showing the locations of the threats and non-threats will be provided for the images. It is expected that the Subcontractor shall use half of the images with their keys for training the algorithms and the other half shall be used for validation (third party evaluation) purposes. The Subcontractor shall not use the key to the second half of the data other than for the validation and reporting of the performance of its algorithm (not for training). The Subcontractor has 45 business days from the receipt of datasets and the Subcontract to:

- Run their detection/classification algorithms on the data;
- Deliver a final report describing their performance by generating Receiver Operator Characteristic (ROC) curves using their algorithm.;
- Deliver a copy of the third party's executable software (already trained and validated by the datasets) to LLNL accompanied by a user manual.

LLNS will evaluate the performance of the same algorithm on another separate set of data. LLNS' evaluation of the Subcontractor's algorithm will be documented in a final report within 30 days of receiving the executable code. This report will be sent to TSA and the report may be disseminated to the Subcontract at TSA's discretion.

[1] Threat image Projection.

2. Image Data

LLNS will provide a total of 360 images from two different DR/TRX. 180 images from each scanner; including 90 images with threat and another set of 90 images with "non- threat" materials with the following categories:

- No clutter/ no attenuation;
- Medium clutter/ medium attenuation;
- High clutter/ high attenuation.

1) *Scanners*

   The data is obtained from two different DR/TRX scanners. LLNS will provide the scanners which will be designated scanner “A” or scanner “B” in the Digital Imaging and Communications in Medicine (DICOM) data element (0x0008, 0x1090), Manufacturer Model Name (see readme file that is sent separately when TSA-3rd Party NDA is signed). These two scanners are both single view and dual energy. The Subcontractor shall decide whether it wants to train, validate and be evaluated on only one or both scanners.

2) *Threats*

   The threat will be labeled using a code name and many but not all will be liquids in Nalgene bottles of three volumes. Some other container types may include glass or Thermos bottles and some commercially available non-threat containers. Most containers are plastic and full. Threats and non-threats liquids can exist in the following categories:

   A) Bin data:

      a) Liquids (Nalgene and other bottles in bins);

      b) Bottles in 3:1:1 baggies;

   B) Luggage data:

      a) Liquids (Nalgene and other bottles in bags);

      b) 3:1:1 baggies.

   There might be multiple threat items in one image and the bottles will be in different orientations. The minimum volume to be detected is 50 ml; algorithm should alarm on threat greater than or equal to 50 ml.

3) *Image data*

The supplied DR/TRX images are derived from the original dual-energy data produced from scanners and converted to DICOM compliant format[i]. TSA will send a set of data files and a readme file to the Subcontractor once a Non-Disclosure Agreement (NDA) between TSA and the Subcontractor is signed. There is no image processing of the irradiance DR/TRX data. In some cases where the two energy images are originally combined into a single file, the data will be unfolded and provided as two (high and low energy channel data) separate images. Also, where more than one subject may have been depicted in a single image, the image will be extracted to include only one object group (luggage, bin etc).

4.) *Keys*

LLNS will provide keys to the images by defining a bounding box around each threat and most non-threat items (See Appendix A). Each bounding box will have a specific x-y coordinate system with upper left corner of the image representing (0,0). The bounding boxes will be defined by four coordinate points (each bounding box will be a quadrilateral). Keys will be provided in text file that includes:

File names;
Number of threats;
Number of bin images;
Number of luggage images;
Bounding box for each threat;
Bounding box for each non-threat liquid/gel.

Algorithms

The goals are to detect and differentiate liquid explosive threats from non-explosive liquids and also find all liquids in carry-on items using images described in the previous section to maximize threat detection levels while minimizing the level of false alarms.

1) *Reporting*

Algorithms should operate in automated threat detection (ATD) using two modes, bin mode and luggage mode as described below.

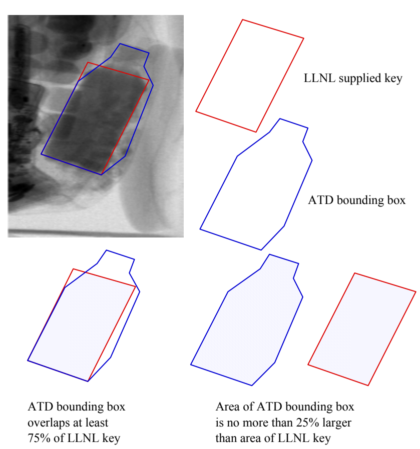
Mode A: Bins with threat and non-threat liquids either in exempt liquid form or 3-1-1 baggies;

Mode B: (B1) Luggage with a possibility of concealed liquid bottles or 3-1-1 baggies inside and (B2) possibly liquid explosive threat detection.

Once the two modes (bin and luggage) are executed, it is expected that the liquid threats and non-threats will be identified in mode A for bins and possibly mode B2 for luggage. These modes are more fully explained in 2) Scoring.

2) *Scoring*

It is desired that scoring is performed based on Rate of detection (Rd) and Rate of false alarm (Rfa) and reported by generating a Receiver Operating Characteristic (ROC) curve. A true detection is reported when the Subcontractor ATD algorithm results in at least a 75% overlap in area of the ATD algorithm bounding box to the bounding box provided in the validation key dataset and the ATD bounding box is not more than 25% larger in area than the bounding box in the key (Figure 1). Otherwise this is recorded as a missed detection. The parameters [e.g. thresholds or features (texture)] adjusted and fixed to generate the ROC curves should be clearly defined and documented in the third party report. If ROC curves cannot be generated, at a minimum the algorithm should be run with five parameter sets such that Rd is 50%, 60%, 70%, 80%, and 90% and the Rfa reported.



ATD bounding box overlaps at least 75% of LLNL key

Area of ATD bounding box is no more than 25% larger than area of LLNL key

Figure 1. Limits on ATD bounding box minimum overlap and maximum total area. Key, bounding box and image depicted may not be representative

Rd and Rfa used in the two modes[3] are:

In Mode A (exempt liquids **and** 3-1-1 haggles):

Rd(A)_represents the number of correctly detected threat items divided by the total number of threats;

RAfa(A) represents the number of false positives divided by the number of images; This is for airport data since the number of non-threats is unknown;

RTfa(A) represents the number of false positives divided by the total number of non-threat items (since number of non-threat items is known for Tyndall data).

In Mode B (luggage):

Rd(B l)_represents the number of detected liquid (threats & non-threats) items divided by the total number of threat and non-threat items;

Rfa(B1) represents the number of false positives (non-liquids detected) divided by the number of images;

Rd(B2)_represents the number of correctly detected liquids threats (only threats) divided by the total number of threats;

Rfa(B2) represents the number of false positives (non-threat liquids that alarm) divided by the number of images.

3. Deliverables

The deliverables include a performance report and executable software.

Report

The Subcontractor shall provide a report on the performance of its detection/classification algorithm with bounding boxes that detects liquid bottles and differentiates threats from non-threats. It should specify the parameters of the bounding boxes and be clear whether the algorithm is operating under Mode A or Mode B and if Mode B distinguish between B1 and B2. Reporting should be as a function of volume and averaged across all volumes. The report shall include the ROC curves.

[3] The two modes do not have to be simultaneous for this initial evaluation, but should be in the future. 5

In its report, the Subcontractor shall use the code names for the threats and code names for volumes (to be defined in a separate document). Such report is considered to be at a minimum, Sensitive Security Information (SSI). Unless further directed by LLNS, the Subcontractor shall not submit reports if actual threats are listed without code name. Such a report is considered to be Secret, National Security Information (SNSI) and requires written approval from the LLNS Contract Administrator and LLNS Technical Representative.

Software

The Subcontractor shall provide executable files to LLNS the following Operating system and input/output requirements:

Operating system:

Executable software should run under Windows XP or linux, or can be Matlab or IDL program code.[2]

Input/Output:

1) Input : DICOM compliant DR/TRX images and the desired Rd.
2) Output: ASCII file with the number of threat and non-threat detections. The format for this ASCII file is *given in* Appendix B.

If necessary, the Subcontractor shall also provide on-site assistance in the uploading and use of the executable files.

4. DHS and LLNS Evaluation

DHS and LLNS will review the reports. For the reports that show promising performance, LLNS will evaluate the performance of the algorithm's executable software based on running the software at LLNS on an additional (similar to the training and validation) set of DR/TRX images.

[2] We want to point out that it is difficult to get third party computers into LLNL, so we prefer executable software to run on our computers.

Appendix A
Key File Format

ImgXY_date_time_zz			Number_of_Threats=#			Number_of_Non-Threats=#			
Sample_name1	T/NT	Vol	Area	POx	POy	P1x	P1y	PNx	PNy
Sample_name2	T/NT	Vol	Area	POx	POy	P1x	P1y	PNx	PNy

Where XY=mode and data source:

AA	Mode A, Airport data
AT	Mode A, Tyndall data
BA	Mode B, Airport data
BT	Mode B, Tyndall data

Zz= hi or lo	hi for high energy data, lo for low energy data
#	Number of threats or non-threats in image
Sample_name	Name of sample within specified boundary
T/NT	Threat/Non-Threat status of bounded region
Vol	Volume (ML) of sample (or net weight in grams, with units, e.g., 170g)
Area	Area of bounding region in pixels
POx	x coordinate of first vertex in bounding region
POy	y coordinate of first vertex in bounding region
P1x,y	Second vertex
PNx,y	Last vertex

Example:

ImgAT_103008_170542_hi				Number_of_Threats=3			Number_of_Non-Threats=4						
C8	T	1125	3009	272	159	331	159	331	210	272	210	272	159
A70	T	1125	3000	68	315	126	320	115	370	57	365	68	315
A50	T	1125	3000	65	123	307	121	355	343	184	389	65	123
H2O	NT	1125	3000	274	157	332	156	340	216	275	222	274	157
Prell	NT	175	2000	149	238	153	226	215	161	212	151	149	238
Smuckers	NT	1567g	2300	308	128	314	113	375	56	363	70	308	128
A35	NT	1125	3000	69	313	127	318	114	371	59	366	69	313

Appendix B
ATD Output File Example

;EXAMPLE: MODE A with three ATD detected regions

;

;The name of this file:fnH.txt, where

; (1) high energy data in file fnH.dcm

; (2) low energy data in file fnL.dcm

; Syntax Notes:

; 1. Comments

; a. ; begins comments

; b. ; blank lines are comments

; 2. Key words and values (KeyString: ValueString)

; a. begin in column 1, case insensitive

; b. values follow a delimiter, colon (:) or equal sign (=)

; c. spaces around delimeter allowed

; d. non-required keys can be added by vendor (LLNL may choose ignore)

; e. syntax example: InputHFile: fnH.dcm

; Version Control

Date: 10/23/08

Time: 15:23:23

Software Version: 34.5.1

Vendor: Acme Detection Company

Hardware: PC I486

OS: Linux v5.3.2

; Inputs

ScannerModel: Rapiscan-520B ;scanner model number

InputHFile: fnH.dcm ;high energy image

InputLFile: fnL.dcm ; low energy image

Input RD: 70 ; target RD

MinVol: 50 ; minimum volume

Mode: Auto ; Auto, Bin or Bag

; Detection Results

```
Mode: A                                  ; A (bin) or B (luggage)
NRegions:  3                             ; 3 ATD detected regions
;
; REQUIRED Outputs for Region 1
;
Type:  A                                 ; A, B1 or B2 (for bin mode always A)
                            ;
;
; coordinate convention: (0,0) = upper left corner, positive x = right, positive y = down:
; example: (0, 1) one pixel down from origin, (1,0) one pixel to the right from origin
; polygon in counter clock-wise
;
;
NPoints = 3                              ; 3 points for ATD polygon
20, 40, 40, 50, 30, 30                   ; first coordinate, 2nd 3rd
;
; Optional outputs for Region 1
;
Area = 155                               ; number of pixels inside polygon
Volume: = 120                            ; estimated volume in mL if available
ZeffMean = 7.5                           ; units: atomic number
ZeffStd = 1.5                            ;
RhoMean = 1.2                            ; units: g/cc
RhoStd = 0.7                             ;

;
; Region 2 (similar to above)
;

; Region 3 (similar to above)
;

FIN                                      ; End of File Marker
```

5. Revision History

VERSION	DESCRIPTION	AUTHORS	DATE
1	Conversion to public domain version from version 25 of original report.	Harry Martz Carl Crawford	9/23/09