ALERT ATR Project: Top-Level Technical Specifications

Version 5

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# Preamble

## Executive Summary

The ALERT Center of Excellence at Northeastern University has received funding from the Department of Homeland Security for a project entitled Advances in Automatic Target Recognition (ATR) for CT-Based Object Detection System. This project is also known as Task Order Four and the ATR Initiative. The project addresses improving CT-based explosive detection equipment by developing improved ATR algorithms. The purpose of this document is to provide the technical requirements for the project.

## Scope

This document provides technical requirements for the following aspects of the project.

1. ATR development
2. Portion of the data collection requirements
3. Targets

Technical requirements and details for the software support tools, ground truth labeling techniques, and simulated test images can be found in the additional documentation referenced in Sections 4-6.

## Terms

| **Term** | **Definition** |
| --- | --- |
| Alarm | A label created (declared) by an ATR. The alarm may be a detection or a false alarm; this determination is performed according to specifications of recall and precision using a ground truth label image. |
| Algorithm | The mathematical steps (or recipe) used to perform a defined problem. This definition does not include computer code. |
| ATR label images | Label images generated by an ATR indicating the presence of alarms. |
| ATR log file | The log file created by an ATR |
| Bag | A bag (or bin) that contains targets and non-targets when scanning on the CT scanner. |
| Bounding box | The six-tuple of (xmin, ymin, zmin, xmax, ymax, zmax) in image space. The first pixel in a 3D image file is corresponds to xmin=ymin=zmin=1). |
| Bulk Object | An object that is not a sheet object. Bulk objects include objects of type saline, rubber and clay. |
| Calculated precision/recall | The precision/recall values calculated for a given label in an ATR label image and a given target in a GT label image. If the calculated recall/precision values are greater than or equal to the target recall/precision values, then the ATR label image is considered a detection |
| Corrected data | Raw data (projections) after being corrected for scanner and object imperfections, and the logarithm taken. |
| Correction | A synonym for pre-processing. |
| Detection | A *detection* occurs when a label declared by an ATR matches the ground-truth for a target, where *match* is defined in terms of recall and precision. See Section 2.4 for more details. |
| Detection determination log file | The log file created by the detection determination program containing the score information for a single scan, including the number of detections, misses, and false alarms an ATR produced for the given scans |
| Digital value | The value of a pixel in an image as stored on a disk. This is not the value of the pixel that is reported by a display program such as ImageJ. |
| Dimensions | The length of the bounding box in x, y and z. The x and y dimensions are the length of the bounding box in x and y in pixels times the in-plane pixel size. The z dimension is the length of the bounding box in z in pixels times the slice spacing. |
| False alarm | A false alarm occurs when an ATR produces a label that does not match the requirements for a detection. See Section 2.5 for additional information.  |
| Ground-truth | See Ground-truth label images. |
| Ground-truth label images | Label images showing the locations of targets and pseudo-targets in CT scans. These are created with a ground truth generation program. |
| Height Database | A database (Excel spreadsheet) containing the pixel height of the patient table for each scan. See Section 2.11.3 for additional information. |
| Image | A 3D set of pixels. The set consists of a set of contiguous 2D slices. The types of image are CT images and label images. |
| Incomplete Detection | A detection that occurs with relaxed values of precision and recall. See Section 2.6 for additional information. |
| Label | A set of non-zero pixels in an ATR label image indicating the presence of an alarm at the corresponding location in the physical bag. A set of non-zero pixels in a ground truth label image indicating the presence of a target at the corresponding location in a bag. |
| Label Image | An image showing to which label a pixel belongs. Label images are generated by ATRs (ATR label images) as well as a program used to generate ground truth (ground truth label images). An ATR label image indicates the presence of alarms, while a ground truth label image indicates the presence of targets. |
| Log file | A human-readable output of a program. The suffix of a log file is “.txt” so that it can be opened under Windows. |
| Miss | A miss occurs when an ATR produces no label for a target in the ground truth label image, or produces a label that does not satisfy the recall/precision specifications for a target in the ground truth label image. See Section 2.7 for additional information.  |
| Non-target | An object that an ATR should not detect. If the ATR detects this object, then a false alarm occurs. |
| Object | A physical item contained in a bag, which may be a target, pseudo-target, or a non-target |
| Object database | A database (Excel spreadsheet) containing information about each object. See Section 2.11.1 for additional information. |
| Object form | Objects may be of the following two forms: sheet or bulk |
| Object type | Objects may be of the following three types: saline, clay, or rubber |
| Overall detection summary log file | A log file created by the PD/PFA determination program containing info for a given set of scans including the info for each target (taken from the packing database) as well as whether the target was detected or missed. This log file can be opened in a spreadsheet program, such as Excel, so that the info can be sorted and filtered. |
| Packing database | A database containing information about each object scanned in each bag. See Section 2.11.2 for additional information. |
| PD/PFA determination log file | A log file created by the PD/PFA determination program containing the overall probability of detection and probability of false alarm for a given set of scans that have already been scored by the detection determination program |
| Phantoms | A numerical (mathematical) description of the contents of a bag. Or, a physical piece of luggage containing known geometric shapes. |
| Precision  | The fraction of a label declared by an ATR that overlaps with a target as declared by in the ground truth label image. See Section 2.4 for additional information. |
| Pre-processing | The reconstruction step converting raw data to corrected data. |
| Probability of Detection | For a set of scans, the number of detections divided by number of targets. See Section 2.8 for additional information. |
| Probability of False Alarm | For a set of scans, the number of false alarms divided by the number of non-targets. See Section 2.9 for additional information. |
| Projection data | Collections of line-integrals of objects. |
| Pseudo-target | A target material with sub-minimum mass or a another material with density less than water. A pseudo-target is also a non-target. |
| Raw data | Projection data directly from the x-ray sensor or data acquisition (DAS) |
| Recall | The fraction of a target, as declared in the ground truth label image, that overlaps with a label detected by an ATR. See Section 2.4 for additional information. |
| Researcher | A performer for tasks described in TO4. A synonym of PI. |
| Scan serial number  | A number from one to the number of bags scanned. This number is used as a unique identifier for each bag scanned. |
| Security vendor | A company developing EDS equipment. The equipment may or may not be deployed in the airports in the United States. The list of security vendors includes L-3 Communications, Reveal Detection, Morpho Detection, Analogic, Rapiscan, Smiths and SureScan. |
| Shape file | A description of geometric shapes used by G3D. |
| Sheet Object | A thin object.  |
| Slice | A 2D set of pixels corresponding to a 2D cross-section. The set consists of a set of contiguous slices. The types of slices are CT slices and label slices. |
| Specified precision/recall | The lower bound precision/recall values used in determining whether a label in at ATR label image matches a target in a GT label image |
| Target | An object that an ATR has to detect. The types of targets are saline, clay and rubber. |
| Target form | See “Object form” |
| Target type | See “Object type” |
| Task order | A type of funding vehicle that DHS uses for funding performers. |
| Third-party | A person or group not working for a security vendor. A third-party works in academia or in industry other than the security vendors |
| xpic | An image display program written by Carl Crawford.  |

## Acronyms

| **Term** | **Definition** |
| --- | --- |
| 2D | Two-dimensional |
| 3D | Three-dimensional |
| ADSA | Algorithm Development for Security Applications, a series of workshops conducted at NEU |
| ALERT | Awareness and Localization of Objects-Related Threats, A Department of Homeland Security Center of Excellence at NEU |
| ATR | Automated target recognition |
| CCL | Connected components labeling |
| COE | Center of excellence, a DHS designation |
| CSV | Comma separated values |
| CT | Computerized tomography |
| DAS | Data acquisition system |
| DB | Database (usually an Excel spreadsheet) |
| dder | Executable name for detection determination scoring program |
| DHS | Department of Homeland Security |
| EDS | Explosives detection system. An EDS is composed of a CT scanner, an ATR algorithm, and a baggage viewing workstation. |
| FITS | Flexible Image Transport System – a 3D image format used by the software tools |
| FOV | Field of view |
| G3D | A program for generating projection data and image for a set of geometric shapes contained in a shape file. |
| GT | Ground truth |
| HME | Homemade explosive |
| ID | Identifier– a physical label with an assigned number affixed to objects scanned in the CT scanner |
| LLNL | Lawrence Livermore National Laboratory |
| MHU | Modified Hounsfield Unit – air = 0 MHU and water=1024 MHU. |
| MI | Multiple-image - an image format used by G3D, mmi, xpic and other programs. |
| MVL | MeVisLab |
| NEU | Northeastern University |
| PD | Probability of detection |
| pdpfa | Executable name for PD/PFA scoring program |
| PFA | Probability of false alarms |
| PI | Principal investigator; a synonym of researcher |
| ROC | Receiver operator characteristic |
| satr | Executable name for sample ATR algorithm |
| SME | Subject matter expert |
| SOW | Statement of work |
| SSI | Sensitive security information |
| SSN | Scan serial number |
| TBD | To be determined |
| TO1 | Task Order 1. The Segmentation Initiative |
| TO3 | Task Order 3. The Reconstruction Initiative |
| TO4 | Task Order 4. This project: the ATR Initiative  |
| TSA | Transportation Security Administration |

## Assumptions/Notes

1. This spec will be evolved as necessary.
2. The initial draft is terse by design in order to seed the evolution process.
3. Some tools will not be used by the researchers.

## Document Relationship

This document supersedes the following documents.

[1] Crawford, C. R., “Statement of Work - Advances in Automatic Target Recognition (ATR) for CT-Based Object Detection System – Task Order 4 & ATR Initiative, Version 4, June 12, 2013.

[2] Crawford, C. R., “TO4 (ATR Initiative) Scan Plan,” Version 6, October 13, 2013.

[3] Rupcich, F., and Crawford, C. R., “ALERT ATR Project: Software Tools Specifications,” Version 5, April 12, 2014.

[4] Rupcich, F. “ALERT ATR Project: Ground Truth Labeling,” Version 2, April 12, 2014.

[5] Rupcich, F. “ALERT ATR Project: Simulated Test Images Specification,” Version 2, April 12, 2014.

[6] Crawford, C. R., “ATR Project Level of Difficulty Specification,” February 5, 2014.

[7] Karimi, Seemeen. “Sample Segmentation Software for Segmentation Grand Challenge,” April 30, 2010.

## Background

The Department of Homeland Security (DHS) has requirements for future explosives detection systems (EDS) that include increased probability of detection and decreased probability of false alarm for a larger set of objects and with reduced minimum masses. The larger set of objects includes certain types of homemade explosives (HME). There are indications that these requirements for future EDS equipment may be difficult to achieve with the technologies presently deployed in the field. In order to resolve these issues, DHS has adopted the strategy of augmenting the capabilities and capacities of the vendors of EDS equipment with the involvement of third parties. Third parties are defined as researchers from academia and industry other than the vendors.

DHS has funded ALERT to execute a project denoted the *Automated Target Recognition (ATR) Initiative*, which is also known as *Task Order Four* (TO4). The goal of this project is to involve third parties in the development of ATR algorithms that could eventually be deployed by the incumbent vendors. The work will be led by the Northeastern University component of the ALERT DHS Center of Excellence (COE). The investigators for the projects will be comprised of researchers both within and outside of the current group of people being supported by the COE.

The research is designed with the following outcomes for DHS.

* The program will improve ATRs. The improved target recognition may lead to decreased minimum target mass, increased target population coverage, increased probability of detection and decreased probability of false alarm.
* The program will increase involvement of third parties via the availability of common CT datasets, and tools, which will increase the work in target recognition, and the number of students who can join the workforce of the vendors and DHS.
* The program will foster collaboration between academics, national laboratory personnel and incumbent security industry vendors.

Technical interchange will be facilitated near the end of the project so that the researchers can present their results to the security vendors, DHS and other third-parties. The results will be documented in a final report for DHS.

## Overview of Project

An overview of the project is described in this section.

1. Bags will be packed to represent what is found in stream of commerce in airports.
2. The target materials will be saline, polymer (modeling) clay, and rubber.
3. Targets of any material may be considered “bulk” or “sheet” form. The rule-set for determining whether a target is a bulk or a sheet is described in Section 2.10.3.
	1. Most rubber targets are sheets (exception: rubber rods)
	2. Most saline and clay targets are bulk
4. The bags will be scanned on a medical CT scanner resulting in images of the bags. The scans will be single energy.
5. The contents and their placement in bags will be documented.
6. The voxels corresponding to the targets in the images will be marked and stored in label images. This marking is known as ground truth.
7. ATRs will be developed using the images and the ground truth.
8. The ATRs will be assessed using the following criteria.
	1. Minimizing the probability of false alarm (PFA) for a specified probability of detection (PD)
	2. Minimal use of algorithms for specific target configurations (known as corner cases)
	3. Minimal overtraining on test data
	4. Novelty compared to the prior art
	5. Ability to detect targets in difficult configurations
	6. Potential to be extended to detect additional targets
9. Software will be supplied to compare the results of ATRs with the ground-truth.
10. The following items will be supplied to assist the development of ATRs
	1. A sample (notional) ATR so that common functions (e.g., reading and writing images and results) do not have to be replicated by each PI. The benchmark ATR may be updated as necessary during the course of the project.
	2. The segmentation algorithms developed for the Segmentation Initiative (Task Order 1) may be available for use in this project. Some of the algorithms may be patented.
	3. A bibliography describing related prior art in the ATR field.

# General Requirements

## CT Scanning

See the TO4 (ATR Initiative) Scan Plan for more details pertaining to the scanning specifications and process.

### Scan Characteristics

The CT scans will have the following characteristics.

1. CT scanner: Imatron C-300
2. Image size: 512 x 512
3. Field of view: 475 mm
4. In plane pixel size: (475/512) = 0.928 mm
5. Slice spacing: 1.5 mm
6. Pixel volume: (475/512)^2 \* 1.5 = 1.291 mm3
7. Digital values: air = 0, water = 1024
8. Minimum pixel value: 0 MHU
9. Maximum pixel value: 32,767 MHU
10. File format: FITS (16-bit, unsigned integer)

### CT Scanner Axes

The following axes shall be used for the CT-scanner

1. x: horizontal axis of axial slice
2. y: vertical axis of axial slice
3. z: parallel to direction of table movement for helical scans

### Location Code for Objects Placed in a Bag

A three-letter code is used to note where objects are placed in a bag. The code is of the form xyz, where x, y, and z are letters showing the location along the x, y and z, axes, respectively. The x- and y-axes are split into three sections denoted A, B, and C. The Z-axis is split into four sections denoted A, B, C and D. The following diagram shows some are the location codes map to a bag.



### Preferred Axes for Objects

1. Cylinders: axis of rotation
2. Sheets: Parallel to conveyor belt
3. Cuboids: Longest dimension

### Orientation Codes for Objects

The orientation code is used to specify how the preferred axis of an object is oriented in bag. The values of the code are as follows.

1. Aligned to an axis:
	1. X: aligned to x axis
	2. Y: aligned to y axis
	3. Z: aligned to z axis
2. Not aligned to an axis but in a plane aligned with two axes:
	1. XY: in xy-plane
	2. YZ: in yz-plane
	3. XZ: in xz-plane
3. Other
	1. N: not aligned with an axis and not in plane aligned with two axes

Notes

1. A plus sign (+) sign or minus sign (-) shall be appended to all the orientation codes to show how the preferred axis of an object.

### IDs

1. IDs for targets have to be unique and numeric
2. Each packing or shape of an object has own ID. For example,
	1. Each bottle of saline has its own ID
	2. Each shape (cutting) of a rubber sheet has its own ID
3. The bulk (source) material(s) for targets should also have unique IDs. For example, the box of modeling clay should be given an ID. Each time a piece of clay is cut from the bulk or a piece is molded, it should be given a new ID.

## Images and Files

### Label Images

A label image is a 3D image that indicates if a pixel in a CT image corresponds to a target. A label image is output from a program that generates ground-truth or by an ATR.

* 1. Size: same (# slices = N , # rows = 512, # columns = 512) as CT image from which labels are generated
	2. Sources: ATR program, GT Generator program
	3. Background label: digital value of 0
	4. Foreground values:
		1. ATR label images: positive integers assigned by ATR
		2. GT label images: ID of targets
		3. Maximum value: 65535 (maximum value of unsigned short int)
		4. Labels within a label image do not have to have sequential values (e.g., 1, 2, … N, where N is the number of labels).
	5. General: A label image pixel can be assigned to only one label
	6. Maximum number of labels: 100

### File Compression

1. Files: CT images or label images
2. Algorithms: gzip
3. Application: mandatory

### Image Formats

#### Images

1. Format: 3D FITS, 16-bit, unsigned integer
2. Types: CT images and label images
3. File suffix: .fits

#### Log Files

1. Format: Windows text format; compatible with notepad
2. Types:
	1. ATR log file
	2. Detection determination log files
	3. PD/PFA log files
3. File suffix: .txt, .xls

### Databases

1. Format: CSV (derived from Excel spreadsheets)
2. Types: packing database, object database, height database
3. File suffix: .csv (for software tools), .xls (human readable form)

### File Naming Conventions

Filenames are a single letter followed by the SSN (zero padded to three digits), followed by the extension *fits.gz* (gzipped compressed FITS format). The letter code is as follows:

I – CT image

G – GT label image

A – ATR label image

For example, the CT, GT label, and ATR label images for SSN 50 are I050.fits.gz, G050.fits.gz, and A050.fits.gz, respectively.

NOTE: The SSNs, and thus the filenames, range from 004 to 193. However, due to corrupt/missing data, SSNs 27 and 160 are not used.

## Project FTP Site

1. URL: eng-filetransfer.bu.edu/eng\_research\_TO4
2. Directory structure: TBD

## Detection

A detection occurs when an alarm declared by an ATR *matches* the ground-truth for a target. The term *match* is defined in terms of *recall*, *R*, and *precision, P*. Let *G* correspond to the set of pixels in the ground-truth for a target. Let *S* correspond to the set of pixels declared to be an alarm by an ATR. Then recall and precision are defined as follows.

$$R=\frac{volume\left(G∩S\right)}{volume(G)}$$

$$P=\frac{volume\left(G∩S\right)}{volume(S)}$$

A detection occurs when:

1. For bulk objects: *R*≥0.5 and *P*≥0.5.
2. For sheet objects: *R*≥0.2 and *P*≥0.2

## False Alarm

A false alarm occurs when an ATR creates a label that does not meet the requirements for a detection.

## Incomplete Detection

An incomplete detection is a detection that occurs for the values of precision and recall, as shown in Section 2.4, multiplied by the factor, *alpha*. The default value of alpha is 0.0, which implies that an ATR label that intersects a GT label by at least one pixel meets the requirement for an incomplete detection. However, if an ATR label meets the requirements for a detection for a GT label, then it will not be counted as an incomplete detection for that GT label.

Note the following:

* Incomplete detections ***do not*** count as a detection
* Incomplete detections ***do*** count as false alarms

## Miss

A miss occurs when an ATR produces no label that satisfies the precision and recall specifications for a target in the ground truth label image.

## Probability of detection (PD)

Probability of detection is defined as the number of detections (see Section 2.4) divided by the number of targets present in a set of scans. The set of scans may be less than all the bags in the packing database. There may be different types of PDs for different sets of targets. The following types of PD may be used:

1. For all targets
2. For each type of target
3. For different levels of clutter
4. For different orientations
5. For different locations
6. For combinations of the above

## Probability of false alarm (PFA)

Probability of false alarm is defined as the number of false alarms (see Section 2.5) divided by the number of non-targets for a given set of scans.

## Targets

### Materials

1. Saline doped to have a densities overlapping with other liquids commonly found in bags.
2. Modeling clay (polymer)
3. Rubber

### Mass

1. Minimum mass: 250 g
2. Maximum mass: None

### Thickness (Sheet vs. Bulk)

The following rule-set is used to determine whether an object is a sheet pseudo-target, a sheet target or a bulk target:

thickness < 1/4 “ : sheet pseudo-target

1/4" <= thickness <= 3/8” : sheet target

 thickness >3/8” : bulk target

### Pseudo-Targets

1. Pseudo-targets (PT) are one of the following types
	1. Target materials listed in Section 2.10.1 with masses ≥ 125 g and < 250 g
	2. Targets materials with a thickness less than ¼”
	3. Powders with masses greater ≥ 125 g and density < 1 g/cc
2. ATRs are not required to detect PTs. A detection on a PT will not be considered to be a false alarm.

## TO4 Database

The TO4 database is a version-controlled Excel workbook comprising multiple worksheets containing information about each object and scan. The overall database is further broken down into three individual databases (each is a single spreadsheet in the TO4 database workbook):

1. Object database – contains information about each object
2. Packing database – contains information about each bag
3. Height database -- indicates the height of the patient table for each bag

The software tools use CSV formatted versions of the three database files. The CSV versions of the database files are distributed with the tools package. More detailed specifications of the databases can be found in the ALERT ATR Project: Software Tools Specifications.

### Object Database

The object database contains information about each object (both targets and non-targets) that was scanned for this project, including the ID, object description, material type and form, mass, volume, and dimensions.

### Packing Database

The packing database contains information about each object in each scan, including the ID, location code, orientation code, level of difficulty, and bounding box.

### Height Database

The height database contains the pixel height of the patient table for each scan. It is used by the sample ATR algorithm to zero out the pixels below the patient table for a given CT image.

# ATR Specification

## Owners

1. Jens Gregor, University of Tennessee
2. Synho Do, Massachusetts General Hospital
3. Charles Bouman et al., Purdue University
4. Jun Zhang, University of Wisconsin, Milwaukee
5. Unfunded participants

## Synopsis

1. Detects targets in sets of CT slices.

## Arguments

1. Filename of input FITS CT image
2. Filename of output FITS image label image [default: derived from input filename]
3. Filename of output log file [default: derived from input filename]

## Inputs

1. 3D FITS containing CT images

## Functions

1. Detect targets
2. Determine the following features for each label
	1. Mass
	2. Volume
	3. Density (mean and standard deviation)
	4. Number of voxels
3. Create log file

## Outputs

1. 3D FITS containing label image
2. ATR log file – specified Section 7.

## Deliverables

1. Algorithm description
2. Log files
3. Label images

## Acceptance Criteria

1. Maximize PD and minimize PFA

## Notes

1. The ATR may be based on the sample ATR, satr.c.
2. The bags are scanned at the same height. Therefore, pixels after a TBD tow may be zeroed.
3. Multiple researchers will be developing ATRs. The researchers shall develop their algorithms independently.
4. The input to the ATR shall be images. Projection data (raw and corrected) may be used by the ATR but not reconstructed.
5. There shall not be an upper limit on mass or volume.
6. Detection should be independent of shape, size, location, orientation, clutter, and concealment. This means that the researcher should not try to meet the PFA requirement by not detecting configurations of targets that lead to high false alarms.
7. PD may be weighted to emphasize targets whose images are corrupted by CT artifacts.
8. The researchers are requested to:
	1. Separate the data into training and test sets
	2. Not over-train on the data
	3. Design their ATRs to be extensible so that additional targets can be considered in the future.
9. Containers (e.g., bottles) for liquids are not considered to be part of the target.
10. The ATRs shall be different than the methods presented in the prior art.
11. There is no requirement to report the type of target (e.g., saline, modeling clay or rubber sheet).

# Software Tools Specification

The following software support tools were created to standardize both the scoring of the ATR algorithms and the reporting of PD/PFA. Details can be found in ALERT ATR Project: Software Tools Specifications.

1. Sample ATR
2. Detection determination (scoring)
3. PD/PFA determination
4. Generate PD/PFA
5. GT verification
6. MI to FITS file converter
7. FITS to MI file converter
8. Raw to FITS file converter
9. Merge CT and label images

# Ground Truth Labeling

Semi-automated segmentation and labeling each target was performed to obtain ground truth label images. Details of the ground truth labeling process can be found in ALERT ATR Project: Ground Truth Labeling.

# Simulated Test Images Specification

Simulated test images were generated for testing ATRs. Details can be found in ALERT ATR Project: Simulated Test Images Specification.

# ATR Log File Format

## Synopsis

The purpose of this section is to specify which information should be supplied in the ATR log file when an ATR program processes a set of images. The format of the information is also specified.

## Format

1. One ATR log file per scan.
2. Contains information about processing one set of CT slices.
3. Contains information for all labels including the background label.
4. File should have .txt suffix and be readable by *notepad* in Windows.
5. Information is supplied as *[keyword] value* with an optional *(units)* inserted after the keyword.
6. Whitespace can be added.
7. Keywords are not case sensitive.
8. Pixel indices begin with (1,1,1).
9. The order of keywords has to match table indicated the following section.
10. If a keyword is not applicable, then its value should be left blank.
11. The symbol > means tag repeats.
12. MHU are modified Housfield Units (HU). Air and water are 0 MHU and 1024 MHU, respectively.
13. The volume of a pixel is specified in Section 2.1.1.
14. <space> means insert blank line in an ATR log file at this point.
15. See below for a sample log file.
16. Include filename suffixes when filenames are reported.
17. All text after a pound sign (#) is considered to be a comment or additional information supplied by an ATR.

## Information

| **Keyword** | **Units** | **Contents** | **Remarks** |
| --- | --- | --- | --- |
| [Performer] |  | Name of institution or researchers or both |  |
| [Date] |  | Date images processed | May include time. |
| [Time] |  | Time images processed | May include date. |
| [Image-name] |  | Image filename | Set of CT slices |
| [Image-format] |  | Format of input image file used | FITS is the only accepted format. |
| [CT-columns] |  | Number of columns per image |  |
| [CT-rows] |  | Number of rows per image |  |
| [CT-slices] |  | Number of 2D images in the input file |  |
| [CT-first] |  | First slice used in the set of 2D slices. | Should be one if all the input slices are used. |
| [CT-count] |  | Number of 2D slices processed. | Should be equal to the [CT-slices] if all the slices are used. |
| [CT-fov] | (mm) | Scanner FOV |  |
| [CT-pixel] | (mm) | Pixel size |  |
| [CT-slice-space] | (mm) | Slice spacing |  |
| [CT-offset] | (MHU) | Value subtracted to make the CT value of air equal to 0 MHU. |  |
| [CT-dimension-z] | (mm) | [CT-count] \* [CT-slice-space] |  |
| [CT-mean] | (MHU) | Mean of all pixels sent to the ATR. |  |
| [CT-mass] | (g) | Mass of all the pixels sent to the ATR. | Mass is estimated using: CT/1024 \* voxel size |
| [Label-name] |  | Filename of output label image |  |
| [Label-format] |  | Format of output label image | FITS is the only accepted format. |
| [OS] |  | Operating system | E.g., Windows or Linux |
| [Executable] |  | filename of executable program |  |
| [Version] |  | Version # of ATR algorithm  |  |
| [Total-labels] |  | Total number of labels detected | Excluding background |
| <space> |  |  |  |
| >[Label-num] |  | Label number | 1. From 0 to total-labels
2. 0 is for the background
3. This and remaining keywords are repeated for each of the labels segmented
4. Calculations performed on CT pixels are limited to the CT pixels that have the indicated label value.
 |
| >[Label-id] |  | Value of label in the label image | Does not have to match target ID |
| >[Slice-first] |  | First slice containing label | This and the next five keywords are for a rectangular bounding box in the image coordinate system |
| >[Slice-last] |  | Last slice containing label |  |
| >[Row-first] |  | First row containing label |  |
| >[Row-last] |  | Last row containing label |  |
| >[Column-first] |  | First column containing label |  |
| >[Column-last] |  | Last column containing label |  |
| >[Dimension-x] | (mm) | (Column-last – Column-first+1) \* pixel size |  |
| >[Dimension-y] |  | (Row-last – Row-first+1) \* pixel size |  |
| >[Dimension-z] |  | (Slice-last – Slice-first +1) \* slice spacing |  |
| >[Voxels] |  | Voxels segmented – that is, number of voxels with value *Label-id* |  |
| >[Mass-CT] | (g) | Mass of label using CT values | Mass is estimated using: CT/1024 \* voxel size |
| >[Volume] | (cc) | Volume of label |  |
| >[Density –CT] | MHU | Sum of values of the voxels divided by the number of voxels detected |  |
| >[Density-std-CT] | MHU | Standard deviation of the values of the CT voxels  |  |
| ><space> |  |  |  |

## Sample ATR Log File

[Performer] Carl Crawford, Csuptwo

[Date]: Thu Dec 12 13:23:25 2013

[Time]: Thu Dec 12 13:23:25 2013

[CT-name] I076.fits

[CT-format] FITS

[CT-columns] 512

[CT-rows] 512

[CT-slices] 270

[CT-first] 1

[CT-count] 270

[CT-fov] (mm) 475.00

[CT-pixel] (mm) 0.93

[CT-slice-space] (mm) 1.50

[CT-offset] (MHU) 0

[CT-dimension-z] (mm) 405.00

[CT-mean] (MHU) 22.22

[CT-mass] (g) 1982.50

[Label-name] label.fits

[Label-format] FITS (16-bit unsigned short)

[OS] Linux

[Executable] satr

[Version] $Id: satr.c,v 1.1 2013/10/18 13:55:33 franco Exp franco $

# Total-labels includes label (0) for background

[Total-labels] 2

# \*\*\*\* satr program variables \*\*\*\*

#min mass (g) = 50.00

#low threshold (MHU) = 1000

#high threshold (MHU) = 2000

#ccl delta (MHU) = 100

#connectivity = 0

# Label-num=0 is the background

[Label-num] 0

[Label-id] 0

[Slice-first] 1

[Slice-last] 270

[Row-first] 1

[Row-last] 512

[Column-first] 1

[Column-last] 512

[Dimension-x] (mm) 475.00

[Dimension-y] (mm) 475.00

[Dimension-z] (mm) 405.00

[Voxels] 69751026

[Mass] (g) 459.12

[Volume] (cc) 90051.12

[Mean] (MHU) 5.22

[Standard-deviation] (MHU) 83.69

[Label-num] 1

[Label-id] 1

[Slice-first] 1

[Slice-last] 72

[Row-first] 185

[Row-last] 350

[Column-first] 163

[Column-last] 374

[Dimension-x] (mm) 196.68

[Dimension-y] (mm) 154.00

[Dimension-z] (mm) 108.00

[Voxels] 382970

[Mass] (g) 578.37

[Volume] (cc) 494.43

[Mean] (MHU) 1197.85

[Standard-deviation] (MHU) 120.40

# Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Version** | **Date** | **Author** | **Revisions** |
| 1 | 12/2/2013 | CRC | Initial release of top-level spec. Based on latest versions of scanning spec, SOW and tool-spec.  |
| 2 | 12/12/2013 | CRC + FJR | Changes based on in part based on FJR’s editing and Jens’s comments. |
| 3 | 4/6/2014 | CRC, FJR | Additional revisions. Moved SW Tools specifications to SW Tools Spec document. |
| 4 | 4/12/2014 | CRC, FJR | Reference other documents. Re-organized. |
| 5 | 5/24/2014 | FJR | Further defined “Incomplete Detections” |