ALERT ATR Project: Software Tools Specifications

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# Introduction

This document is a technical specification and reference guide for the software tools and associated log files for the ALERT ATR project (also denoted Task Order 4 [TO4]). The information in this document supersedes that in the Top-Level Technical Specifications document. The tools that are described in this document are summarized in the following table.

Table 1: TO4 Software Tools

| **Executable/Program Name** | **Software Tool** | **Description** |
| --- | --- | --- |
| satr | Sample ATR | Sample ATR. Performs connected component labeling (CCL) on an input CT image and produces a label image. Demonstrates how to read CT images and produce label and log files. |
| dder | Detection Determination (scoring) | Scores an input label image produced by an ATR against the corresponding ground truth (GT) image based on specified values of precision and recall and outputs the results to two log files |
| pdpfa | PD/PFA Determination | Compiles the results from a specified set of images that have been scored using *dder*, determines probability of detection and probability of false alarm statistics, and writes results to four log files. |
| gen\_pdpfa.sh | Generate PD/PFA | Runs a specified ATR on a specified set of CT images to produce a set of corresponding label images, scores the label images against the GT label images using *dder*, and then generates probability of detection (PD) and probability of false alarm (PFA) statistics using *pdpfa*. |
| gtver | GT Verification | Verifies GT label images by cross-checking the mass and bounding box of each target calculated from the GT label images against the mass and bounding box recorded in the object and packing databases. |
| mi2fits | MI to FITS File Converter | Converts an mi-formatted file to a FITS-formatted file. |
| fits2mi | FITS to MI File Converter | Converts a FITS-formatted file to an mi-formatted file. |
| raw2fits | Raw to FITS File Converter | Converts a raw-formatted file (unsigned short, short, unsigned int, int, or float) to a FITS-formatted file. |
| mmi | Merge CT and Label Images | Overlays a label image onto a CT image. The resultant merged mi formatted image can be viewed using xpic. |

# Definitions

See ALERT ATR Project: Top-Level Specifications for the list of terms and acronyms for this project, as well as for details regarding targets vs. pseudo-targets, detection, false alarms, misses, probability of detection, probability of false alarm, recall, and precision.

# General

## Supported Operating Systems

The tools are supported on the following operating systems:

1. 32-bit Linux
2. 64-bit Linux
3. 64-bit Mac OS X (version 10.x)

## Required Packages

Below is a list of packages required to be installed on Linux and OSX before running the tools:

1. dos2unix
2. gcc
3. make
4. rcs

## CRC Parse Library

The TO4 software tools rely on the parse library from the *crc* support package, a package of tools written by Carl Crawford. The parse library comes bundled with the TO4 tools. Additional information about the crc package can be found in the crc documentation, which can be found at <http://www.csuptwo.com/crawford_software.html> .

## Command Line Functionality

Each of the tools accepts command line options and flags, all of which are optional. In other words, the tools can be run without any command line options, in which case a set of default command line options will be used.

Passing a “?” to any of the tools except *gen\_pdpfa.sh* will give the help dialog. For *gen\_pdpfa.sh*, the –h flag gives the help dialog.

## 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 row height of the patient table for each bag

The software tools use CSV-formatted versions of the three database files. The CSV versions are created by saving an Excel spreadsheet as a .csv file. The CSV versions of the database files are distributed with the tools package and specified in the following sections.

### Object Database

The object database contains the following information about each object in the following order:

1. ID
2. Description (in words); maximum of 10 words
3. Task Order (TO) -- the Task Order in which the object was procured
4. Type
	1. n = non-target
	2. x or ? = don’t know enough information about object (probably from TO1 or TO3)
	3. t = target
	4. pt = pseudo-target
5. Sub-type
	1. E = enclosure (may contain target or non-target or be empty)
	2. c = clay
	3. r = rubber
	4. s = saline
6. Form
	1. sheet
	2. bulk
7. Merged – Only applicable for type “target.” If “y”, then this target is a merged target composed of the two targets indicated by the IDs in the “Parent” and “Container” fields. Only targets of the same type can be considered merged
8. Parent
	1. If “Merged” field is “n”, then this is the ID of the material that was put into the container specified in the “container” field of this database. When a parent ID is present, this is considered to be a specimen (e.g., saline packed in a container). The ID should have an "S" on the label.
	2. If “Merged” field is “y”, then this field is the ID of the first target composing the merged target.
9. Container
	1. If “Merged” field is “n”, then this field is the ID of container used in the construction of a specimen.
	2. If “Merged” field is “y”, then this field is the ID of the second target composing the merged target
10. Vendor and part number
11. Dimension 1 [mm]
12. Dimension 2 [mm]
13. Dimension 3 [mm]
14. Dimensions [mm] – can specify dimensions in X x Y x Z format
15. Volume (of container and contents) [cc]
16. Mass [g]

Note: A target may be scanned in multiple bags. A target retains the same ID across all scans in which it is present. If a target is reshaped or a liquid is put in a new container, the target will be given a new ID. For example, if a piece clay is reshaped, the clay will be given a new ID.

### Packing Database

The packing database contains the following information about each object in each scan in the following order.

1. SSN
2. ID
3. Description (in words): A maximum of 20 words.
4. isChild? -- Indicates whether this target is contained in a merged target within this bag. This is to assure that only the merged target (and not the individual targets it is composed of) is accounted for during scoring
5. Location code: A three letter designation of the form xyz, where x, y and z are either A, B or C. The details of this code are specified in the scanning specification.
6. Orientation code: The code is x, y, z, for the object’s preferred axis aligned with x, y, z axes of the bag, respectively. The code ‘n’ means the object is not aligned with any axis. The preferred axes of objects are defined in the scanning specification.
7. Level of Difficulty (LOD)
	1. Low
	2. High
8. x\_min – bounding box xmin [pixels]
9. x\_max – bounding box xmax [pixels]
10. y\_min – bounding box ymin [pixels]
11. y\_max – bounding box ymax [pixels]
12. z\_min – bounding box zmin [pixels]
13. z\_max – bounding box zmax [pixels]

### Height Database

The height database contains the following information about each scan in the following order:

1. SSN
2. Height – row number of patient table

## File Formats

### Images

All CT, GT label, and ATR label images must be in FITS format (16-bit, unsigned integer). In addition, the files should also be compressed using *gzip*. The extension of these files is .fits.gz.

### Log Files

Log files are written as either text (.txt) or tab-delimited (.xls). Tab-delimited (.xls) log files can be opened in Excel to facilitate filtering and sorting of information.

### Database Files

The software tools use CSV formatted versions of the object, packing, and height database files. The CSV versions of the database files are distributed with the tools package. See Section 3.5 for more details.

## Image 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.

# Building the Tools

The following instructions demonstrate how to build the tools on both Linux and OSX.

1. Create a working directory for the TO4 software tools. For the sake of clarity, we will refer to this directory as my\_dir/.
2. Download the latest to4-tools tar file from the ftp site (/**eng\_research\_TO4/tools/**) and place it into my\_dir/.
3. Untar the to4-tools tar file (tar xzvf *filename.tar.gz*). This will automatically create a directory called to4-tools\_vXX/, where XX is the version number. In addition, a soft-link called to4-tools/ will be created. This soft-link will always point to the most recent to4-tools\_vXX/ directory.
4. cd into to4-tools/
5. Type "make" to build the tools. In addition, this will automatically create four directories in my\_dir/, but only if they have not already been created (i.e., these directories will not be overwritten upon subsequent builds). These four directories are the default directories used by *gen\_pdpfa.sh*. They are
	1. ct/ --> *gen\_pdpfa.sh* will look for CT images in this directory by default
	2. gt/ --> *gen\_pdpfa.sh* will look for GT label images in this directory by default
	3. labels/ --> *gen\_pdpfa.sh* will write ATR label images to this directory by default
	4. logs/ --> *gen\_pdpfa.sh* will write log files to this directory by default
6. Repeat Steps 2-5 each time a new to4-tools tar file is uploaded to the FTP site.

# Generating PD/PFA Results Using gen\_pdpfa.sh

## Overview

*gen\_pdpfa.sh* is a (bash) shell script that performs the following functions:

1. Run a user-specified ATR (*satr* by default) on a user-specified set of CT images to produce a set of corresponding label images
2. Run *dder* to score the label images produced in Step 1 against the respective ground truth (GT) label images
3. Run *pdpfa* using results produced in Step 2 to generate probability of detection (PD) and probability of false alarm (PFA) statistics for the set of specified CT images. These statistics are output to several log files (see Section 7.3 for more details on the *pdpfa* log files).

**Researchers are required to run this script so that all ATR results may be reported in a standardized format.**

## Running gen\_pdpfa.sh

The following instructions describe how to run *gen\_pdpfa.sh* with no command line options (i.e., using the default behavior). (For more information regarding specifying command line options for *gen\_pdpfa.sh*, see Section 6.4.) For the sake of clarity, we will assume the user has a working directory named my\_dir/.

1. Build the latest version of the software tools (see Section 4)
2. Download the CT images from the FTP site and place them into my\_dir/ct/
3. Download the latest GT label images from the FTP site and place them into into my\_dir/gt/
4. cd into my\_dir/to4-tools/
5. Run ./gen\_pdpfa.sh

By default, *gen\_pdpfa.sh* will run *satr* for all CT images in my\_dir/ct/ (for which a GT label image exists in my\_dir/gt/), and it will place all label images produced by *satr* into my\_dir/labels/. *dder* will then score each label image in my\_dir/labels/ against the corresponding GT label image in my\_dir/gt/ directory.

Log files produced by *satr* (or the specified ATR program) will be placed into my\_dir/logs/atr\_logs. Log files produced by *dder* will be placed into my\_dir/logs/dder\_logs. *pdpfa* will compile the results from the *dder* log files and generate PD and PFA log files, which will be placed into my\_dir/logs/pdpfa\_logs. *gen\_pdpfa.sh* also generates a log file containing the command line options used, as well as the standard output of calls to *satr*, *dder*, and *pdpfa*. The *gen\_pdpfa.sh* log file will be placed in my\_dir/logs/pdpfa\_logs. Descriptions of all log files can be found in Section 7.

## Standardized Reporting

The five log files located in my\_dir/logs/pdpfa\_logs after running *gen\_pdpfa.sh* are the ones used for standardized reporting for this project (NOTE: the following list shows the default log file names):

1. gen\_pdpfa\_log.txt
2. pdpfa\_log\_summary.txt
3. pdpfa\_log\_pds.xls
4. pdpfa\_log\_detections.xls
5. pdpfa\_log\_false\_alarms.xls

# Tools Specifications

Each of the software tools described in this section allows for input of command line options and flags. If no options are provided, the program will run with a set of default arguments (specified in the Options table for each software tool). The default behavior of each program can be changed using the options and flags described in the following sub-sections.

## satr

### Synopsis

*satr* is a “sample ATR” program. It takes as an input a CT image, performs erosion (using a 3x3x3 kernel) and connected component labeling (CCL) on it, and outputs a label image and a log file. *satr* calculates the mass of objects and has a classifier based only on mass and density.

*satr* was originally written by Seemeen Karimi [3] and modified by Carl Crawford for this project.

### Input Files

1. CT image [.fits.gz, .mi]

### Output Files

1. Label image [.fits.gz, .mi]
2. Log file [.txt]

### Standard Output

1. Program name
2. Start time
3. RCS ID
4. File format
5. CT image filename
6. Label image filename
7. Log filename
8. Height database filename
9. Number of rows in images
10. Number of columns in images
11. Number of slices in images
12. Number of slices processed
13. FOV [mm]
14. Pixel size [mm]
15. Offset [MHU]
16. Slice Spacing [mm]
17. Minimum mass [g]
18. Lower threshold [MHU]
19. Upper threshold [MHU]
20. CCL delta [MHU]
21. Connectivity type
22. Number of labels produced
23. End time

### Flags

|  |  |
| --- | --- |
| **Flag** | **Synopsis** |
| ? | Print the help dialog |
| -d | Increment the debug flag |
| -m | Use .mi file format instead of FITS |
| -p | Do not print the program information to the command line |

### Options

| **Option** | **Default Argument** | **Synopsis** |
| --- | --- | --- |
| if | ct.fits.gz | Filename of input CT image. By default, this file must be a gzipped FITS file (i.e., extension is .fits.gz). If no extension is specified in the argument and the –m option is not used, then .fits.gz will automatically be appended. If the –m option is used, then .mi will automatically be appended. |
| of | label.fits.gz | Filename of output label image. By default, the file will be written as a gzipped FITS file (i.e., extension is .fits.gz). If no extension is specified in the argument and the –m option is not used, then .fits.gz will automatically be appended. If the –m option is used, then .mi will automatically be appended. |
| logfn | log.txt | Filename of output log file. |
| hdbf | hdb.csv | Filename of height database file (.csv format). This file contains the row height (in pixels) of the patient table for each SSN, which is used to zero out below the patient table. This file comes packaged with the tools and is located in to4-tools/dbase/hdb.csv. |
| spacing | 1.5 | Spacing between slices [mm]. |
| first | 1 (first slice in image) | The slice of the image at which to begin processing. |
| count | 0 (process all slices) | Number of slices to process |
| fov | 475 | Image field of view [mm] |
| offset | 0 | Image offset [MHU]. This value is subtracted from each voxel before running CCL. It should be used in the case of an image that does not have air = 0 MHU. |
| lt | 1000 | Lower threshold for acceptable pixel values used during labeling [MHU] |
| ht | 2000 | Upper threshold for acceptable pixel values used during labeling [MHU] |
| ccldelta | 100 | Maximum absolute value of the difference between neighbor values used during merging [MHU] |
| minmass | 50 | Minimum mass to be considered a label [g] |
| connectivity | 0 | Connectivity type. For 2D: 0=edge, 1=edge and vertex. For 3D: 0=face, 1=face, edge, and vertices. |

## dder

### Synopsis

*dder* is the “detection determination” program. It scores an input label image produced by an ATR against the corresponding GT image based on specified values of precision and recall and outputs the results to two log files.

### Input Files

1. ATR label image [.fits.gz]
2. GT label image [.fits.gz]
3. Object database file [.csv]
4. Packing database file [.csv]

### Output Files

1. dder summary log file [.txt] – summary scoring information
2. dder false alarm log file [.xls] – information for each false alarm

### Standard Output

1. Program name
2. Start time
3. RCS ID
4. ATR label image filename
5. GT label image filename
6. Object database filename
7. Packing database filename
8. Summary log filename
9. False alarm log filename
10. Precision (target, bulk)
11. Recall (target, bulk)
12. Precision (target, sheet)
13. Recall (target, sheet)
14. Precision (pseudo-target, bulk)
15. Recall (pseudo-target, bulk)
16. Precision (pseudo-target, sheet)
17. Recall (pseudo-target, sheet)
18. Alpha parameter
19. End time

### Flags

|  |  |
| --- | --- |
| **Flag** | **Synopsis** |
| ? | Print the help dialog |
| -p | Do not print the program information to the command line |

### Options

| **Option** | **Default Argument** | **Synopsis** |
| --- | --- | --- |
| ifn\_atr | atr.fits.gz | Filename of input label image. This file must be a gzipped FITS file (i.e., extension is .fits.gz). If no extension is specified in the argument, then .fits.gz will automatically be used. |
| ifn\_gt | gt.fits.gz | Filename of input GT label image. This file must be a gzipped FITS file (i.e., extension is .fits.gz). If no extension is specified in the argument, then .fits.gz will automatically be used. |
| ifn\_odb | odb.csv | Filename of object database (.csv format). This file comes packaged with the tools and is located in to4-tools/dbase/odb.csv. |
| ifn\_pdb | pdb.csv | Filename of packing database (.csv format). This file comes packaged with the tools and is located in to4-tools/dbase/pdb.csv. |
| ofn\_log | dder\_log | Basename used in generating the filenames for the two log files output by *dder*. The argument should not include an extension. The SSN will be parsed from the input GT label image filename and automatically appended to the basename of the two log files, along with each log file’s suffix and extension. For example, if the basename is “dder\_log”, and *dder* is being run for SSN 6, then the two log file names will be dder\_log\_summary\_006.txt and dder\_log\_false\_alarms\_006.xls. |
| p\_bulk | 0.5 | Precision for bulk targets |
| r\_bulk | 0.5 | Recall for bulk targets |
| p\_sheet | 0.2 | Precision for sheet targets |
| r\_sheet | 0.2 | Recall for sheet targets |
| p\_pt\_bulk | 0.5 | Precision for bulk pseudo-targets |
| r\_pt\_bulk | 0.5 | Recall for bulk pseudo-targets |
| p\_pt\_sheet | 0.1 | Precision for sheet pseudo-targets |
| r\_pt\_sheet | 0.1 | Recall for sheet pseudo-targets |
| alpha | 0.0 | Multiplier used for determining when an “incomplete detection” occurs. An incomplete detection occurs when the calculated precision and recall are both greater than or equal to alpha times the specified precision and recall (where the specified precision and recall are p\_bulk, r\_bulk, p\_sheet, r\_sheet, p\_pt\_bulk, r\_pt\_bulk, p\_pt\_sheet, and r\_pt\_sheet). Incomplete detections are reported in the *dder* log files.**NOTE:** Incomplete detections still count as false alarms, since they do not meet the specified precision/recall for a detection. The ATR labels that generate an incomplete detection can be found under the “False Alarms” section of the *dder* Summary Log File, as well as in the *dder* False Alarms Log File. An incomplete detection is any false alarm reported in the log file that has intersecting GT labels reported. In other words, intersecting GT labels for a false alarm are only reported if the ATR label meets the specified precision/recall for an incomplete detection (alpha\*p, alpha\*r), AND the ATR label and GT label intersect by at least one pixel (for the case in which alpha = 0). |

## pdpfa

### Synopsis

*pdpfa* compiles the results from a specified set of images that have been scored using *dder*, determines probability of detection and probability of false alarm statistics, and writes results to four log files.

### Input Files

1. dder log list file (contains list of *dder* log files from which to read scoring information) [.txt]
2. Object database file [.csv]
3. Packing database file [.csv]

### Output Files

1. pdpfa summary log file [.txt] – summary PD/PFA information
2. pdpfa detections log file [.xls] – indicates whether each target was detected or missed
3. pdpfa pds log file [.xls] – PD statistics
4. pdpfa false alarm log file [.xls] – information for each false alarm produced

### Standard Output

1. Program name
2. Start time
3. RCS ID
4. Input list filename
5. Object database filename
6. Packing database filename
7. Output log basename
8. Output summary log filename
9. Output detections log filename
10. Output false alarm log filename
11. Output PD log filename
12. End time

### Flags

|  |  |
| --- | --- |
| **Flag** | **Synopsis** |
| ? | Print the help dialog |
| -p | Do not print the program information to the command line |

### Options

| **Option** | **Default Argument** | **Synopsis** |
| --- | --- | --- |
| ifn\_list | list.txt | Filename of .txt file containing the filenames of the *dder* summary log files from which to read scoring data. Each filename should be printed on a separate line, e.g.:/home/franco/to4-tools/logs/dder\_log\_summary\_006.txt/home/franco/to4-tools/logs/dder\_log\_summary\_007.txt/home/franco/to4-tools/logs/dder\_log\_summary\_008.txtThe probability of detection and probability of false alarm statistics calculated by *pdpfa* are for only those SSNs corresponding to the *dder* log files specified in this list file. |
| ifn\_odb | odb.csv | Filename of object database (.csv format). This file comes packaged with the tools and is located in to4-tools/dbase/odb.csv. |
| ifn\_pdb | pdb.csv | Filename of packing database (.csv format). This file comes packaged with the tools and is located in to4-tools/dbase/pdb.csv. |
| ofn\_log | pdpfa\_log | Basename used in generating the filenames for the four log files output by *pdpfa*. This argument should not include an extension. |

## gen\_pdpfa.sh

### Synopsis

*gen\_pdpfa.sh* is a (bash) shell script that runs a specified ATR on a specified set of CT images to produce a set of corresponding label images, scores the label images against the ground truth (GT) label images using *dder*, and then generates probability of detection (PD) and probability of false alarm (PFA) statistics using *pdpfa*.

### Input Files

1. CT image(s) [.fits.gz]
2. GT image(s) [.fits.gz]
3. Label image(s) [.fits.gz]
4. Object database file [.csv]
5. Packing database file [.csv]
6. Height Database file [.csv]
7. List of SSNs for which to calculate PD and PFA statistics (This file is optional. By default, *gen\_pdpfa.sh* will run on all SSNs for which both a CT and GT label image exist in the specified directories).

### Output Files

Because *gen\_pdpfa.sh* runs *satr*, *dder*, and *pdpfa*, its output includes log files generated by those programs. The following log files are generated by *satr*, *dder*, and *pdpfa* after they are called by *gen\_pdpfa.sh*:

1. satr summary log file for each SSN [.txt]
2. dder summary log file for each SSN [.txt]
3. dder false alarm log file for each SSN [.xls]
4. pdpfa summary log file [.txt]
5. pdpfa detections log file [.xls]
6. pdpfa pds log file [.xls]
7. pdpfa false alarm log file [.xls]

The following log files are generated by *gen\_pdpfa.sh* itself:

1. dder log list file [.txt] – list of *dder* log files used by *pdpfa* to compile results
2. gen\_pdpfa.sh log file [.txt] – standard output from *satr*, *dder*, and *pdpfa*

### Standard Output

1. Program name
2. Start time
3. CT directory
4. GT directory
5. Label directory
6. Logs directory
7. Label image prefix
8. SSN list filename
9. ATR executable filename
10. ATR args
11. Precision (target, bulk)
12. Recall (target, bulk)
13. Precision (target, sheet)
14. Recall (target, sheet)
15. Precision (pseudo-target, bulk)
16. Recall (pseudo-target, bulk)
17. Precision (pseudo-target, sheet)
18. Recall (pseudo-target, sheet)
19. Alpha
20. End time

### Flags

|  |  |
| --- | --- |
| **Flag** | **Synopsis** |
| -h | Print the help dialog |

### Options

| **Option** | **Default Argument** | **Synopsis** |
| --- | --- | --- |
| -c | ../ct/ (this directory is automatically created by the top-level “Makefile,” and resides one level above the to4-tools/ directory). | Directory containing CT images |
| -g | ../gt/ (this directory is automatically created by the top-level “Makefile,” and resides one level above the to4-tools/ directory). | Directory containing GT label images |
| -l | ../labels/ (this directory is automatically created by the top-level “Makefile,” and resides one level above the to4-tools/ directory). | Directory to which ATR label images are written |
| -o | ../logs/(this directory is automatically created by the top-level “Makefile,” and resides one level above the to4-tools/ directory). | Directory to which *satr*, *dder*, *pdpfa*, and *gen\_pdpfa.sh* log files will be written |
| -x | A | Prefix to be used for each label image produced by *satr*. When *satr* is run, it will use this prefix along with the SSN to create the full label image filename. For example, if the prefix “A” is used, then the label image filename for SSN 6 will be A006.fits.gz. |
| -a | ./satr/satr | Relative or absolute pathname of ATR executable |
| -z | None (no additional arguments are passed to the atr) | List of additional options to pass to the specified ATR. These options and their arguments must be enclosed inside double quotes (“ “). For example:./gen\_pdpfa.sh –z “lt=1500 ht=2200 ccldelta=75”**NOTE:** satr/atr options for specifying the input CT image (if), output label image (of), output log file (logf), and height database filename (hdbf) should NOT be included in the argument for the -z option. This is because the first three options’ arguments change as satr/atr is called on each SSN. In addition, the height database file is passed as a separate argument rather than being included as apart of the –z option. |
| -f | None (program will run for all CT and GT label images that exist in the specified directories) | Filename of .txt file containing list of SSNs for which to calculate PD and PFA statistics. Each SSN should be printed on a separate line, e.g.:67823188 |
| -p | 0.5 | Precision for bulk targets |
| -r | 0.5 | Recall for bulk targets |
| -q | 0.2 | Precision for sheet targets |
| -s | 0.2 | Recall for sheet targets |
| -t | 0.5 | Precision for bulk pseudo-targets |
| -v | 0.5 | Recall for bulk pseudo-targets |
| -u | 0.1 | Precision for sheet pseudo-targets |
| -w | 0.1 | Recall for sheet pseudo-targets |
| -b | 0.0 | Alpha parameter (for incomplete detections). See NOTE for this argument in the table in Section 6.2.6. |

### Notes

While the default ATR is *satr*, you may instead specify your own ATR executable using the –a option. The –z option can then be used to specify additional options and arguments to pass to your ATR. However, there is a caveat to using the –z option. Because the filenames of the input CT image, output ATR label image, and output log file change with each call to *satr* within *gen\_pdpfa.sh* (i.e., for each SSN), these arguments are updated within a loop, and thus cannot be used as part of the –z option. In addition, the *satr* option “hdbf,” which specifies the height database file, also should not be used as part of the –z option. **In effect, this means that your ATR must use the same command line options as *satr* for the following four options: if, of, logf, and hdbf.** See satr.c for how the code is implemented. *gen\_pdpfa.sh* may later be updated to eliminate this restriction of the –z and –a options.

By default, *gen\_pdpfa.sh* will run on all SSNs for which both a CT and GT image exist in the specified ct and gt directories. You may also specify a subset of SSNs to run by using the –f option to specify a file containing only the SSNs you want to run. You can use the “SSN Filter” tab of the TO4 database spreadsheet to help determine subsets of SSNs that may be useful in testing your ATR.

## gtver

### Synopsis

Verifies GT label images by checking the following criteria for a given SSN:

1. CT image and GT label image are same size (number of rows, columns, and slices)
2. GT label IDs match target IDs from packing database
3. Target masses calculated from GT label image and CT image are within +/-50% of those reported in the object database
4. GT label bounding boxes and target bounding boxes in packing database have precision and recall of at least 0.5.

### Input Files

1. CT image
2. GT label image
3. Object database file
4. Packing database file

### Output Files

1. gtver log file

### Standard Output

1. Program name
2. Start time
3. CT filename
4. GT filename
5. Object database filename
6. Packing Database filename
7. Number of errors
8. Verification summary (PASSED or FAILED)
9. End time

### Flags

|  |  |
| --- | --- |
| **Flag** | **Synopsis** |
| ? | Print the help dialog |
| -p | Do not print the program information to the command line |

### Options

| **Option** | **Default Argument** | **Synopsis** |
| --- | --- | --- |
| ifn\_ct | ct.fits.gz | Filename of input CT image. This file must be a gzipped FITS file (i.e., extension is .fits.gz). If no extension is specified in the argument, then .fits.gz will automatically be used. |
| ifn\_gt | gt.fits.gz | Filename of input GT label image. This file must be a gzipped FITS file (i.e., extension is .fits.gz). If no extension is specified in the argument, then .fits.gz will automatically be used. |
| ifn\_odb | odb.csv | Filename of object database (.csv format). This file comes packaged with the tools and is located in to4-tools/dbase/odb.csv. |
| ifn\_pdb | pdb.csv | Filename of packing database (.csv format). This file comes packaged with the tools and is located in to4-tools/dbase/pdb.csv. |
| bn\_log | gtver\_log | Basename used in generating the log filename. The argument should not include an extension. The SSN will be parsed from the input GT label image filename and automatically appended to the basename of the log file. For example, if the basename is “gtver\_log”, and *gtver* is being run for SSN 6, then the log file nameswill be gtver\_log\_006.txt. |

## mi2fits

### Synopsis

Converts an mi-formatted image to a compressed (gzipped) FITS formatted image.

### Input Files

1. mi-formatted image

### Output Files

1. Compressed (gzipped) FITS formatted image

### Standard Output

1. Program name
2. Start time
3. RCS ID
4. Input image filename
5. Input image [#rows #cols #slices]
6. First slice read from image
7. Last slice read from image
8. Number of slices converted
9. Output image filename
10. Output image [#rows #cols #slices]
11. End time

### Flags

|  |  |
| --- | --- |
| **Flag** | **Synopsis** |
| ? | Print the help dialog |
| -p | Do not print the program information to the command line |

### Options

| **Option** | **Default Argument** | **Synopsis** |
| --- | --- | --- |
| ifn | image.mi | Filename of input mi image |
| ofn | [*derived from ifn arg]*.fits.gz | Filename of output gzipped FITS formatted image. Default output filename is same as input filename, but with fits.gz extension. |
| pix | 0.928 | Image pixel size [mm] |
| first | 1 (first slice in image) | The slice of the image at which to begin processing |
| count | 0 (process all slices) | Number of slices to convert |
| bitpix | 1 | FITS file pixel data type (1=16-bit ushort, 2=32-bit float) |

## fits2mi

### Synopsis

Converts a FITS formatted image to an mi formatted image.

### Input Files

1. FITS formatted image (.fits or .fits.gz)

### Output Files

1. mi-formatted image

### Standard Output

1. Program name
2. Start time
3. RCS ID
4. Input image filename
5. Input image [#rows #cols #slices]
6. First slice read from image
7. Last slice read from image
8. Number of slices converted
9. Output image filename
10. Output image [#rows #cols #slices]
11. End time

### Flags

|  |  |
| --- | --- |
| **Flag** | **Synopsis** |
| ? | Print the help dialog |
| -p | Do not print the program information to the command line |

### Options

| **Option** | **Default Argument** | **Synopsis** |
| --- | --- | --- |
| ifn | image.fits | Filename of input FITS image |
| ofn | [*derived from ifn arg]*.mi | Filename of output mi image. Default output filename is same as input filename, but with mi extension. |
| first | 1 (first slice in image) | The slice of the image at which to begin processing |
| count | 0 (process all slices) | Number of slices to convert |

## raw2fits

### Synopsis

Converts a raw-formatted (a.k.a. “flat-file”) to a compressed (gzipped) FITS formatted file.

### Input Files

1. Raw-formatted image (unsigned short, short, unsigned int, int, or float)

### Output Files

1. Compressed (gzipped) FITS formatted image

### Standard Output

1. Program name
2. Start time
3. RCS ID
4. Input image filename
5. Input image [#rows #cols #slices]
6. Input image raw datatype
7. First slice read from image
8. Last slice read from image
9. Number of slices converted
10. Output image filename
11. Output image [#rows #cols #slices]
12. End time

### Flags

|  |  |
| --- | --- |
| **Flag** | **Synopsis** |
| ? | Print the help dialog |
| -p | Do not print the program information to the command line |

### Options

| **Option** | **Default Argument** | **Synopsis** |
| --- | --- | --- |
| ifn | image.raw | Filename of raw formatted image |
| ofn | [*derived from ifn arg]*.fits.gz | Filename of output FITS formatted image. Default output filename is same as input filename, but with .fits.gz extension. |
| dtype | 0 | Raw data type (0=ushort, 1=short, 2=uint, 3=int, 4=float) |
| nr | 512 | Number of rows in input image |
| nc | 512 | Number of columns in input image |
| ns | 1 | Number of slices to convert |
| first | 1 (first slice in image) | The slice of the image at which to begin processing |
| count | 0 (process all slices) | Number of slices to convert |
| bitpix | 1 | FITS file pixel data type (1=16-bit ushort, 2=32-bit float) |

## mmi

### Synopsis

Overlays a label image onto a CT image. The resultant merged mi formatted image can be viewed using xpic with the “wl –o” option.

### Input Files

1. CT image (mi format)
2. Label image (mi format)

### Output Files

1. Merged image (mi format)

### Standard Output

1. Program name
2. Start time
3. RCS ID
4. CT image filename
5. Number of slices used in CT image
6. Label image filename
7. Number of slices used in label image
8. First slice used in label image
9. Label image offset
10. Merged image filename
11. Number of slices processed
12. Mode used (whole, contour, or edge)
13. Multi-color (yes or no)
14. Number of labels
15. End time

### Flags

| **Flag** | **Synopsis** |
| --- | --- |
| ? | Print the help dialog |
| -c | Enables contours mode |
| -e | Enables edge mode (default) |
| -m | Disables multi-color |
| -w | Uses whole labels |
| -p | Do not print the program information to the command line |

### Options

| **Option** | **Default Argument** | **Synopsis** |
| --- | --- | --- |
| cf | ct.mi | Filename of mi formatted CT image |
| lf | label.mi | Filename of mi formatted label image |
| of | merge.mi | Filename of mi formatted output merged image |
| offset | 0 | Image offset [MHU]. This value is subtracted from each voxel before processing. It should be used in the case of an image that does not have air = 0 MHU. |
| ctfirst | 1 (first slice in image) | The slice of the ct image at which to begin processing |
| labelfirst | 1 (first slice in image) | The slice of the label image at which to begin processing |
| first | 1 (first slice in image) | The slice of the ct image at which to begin processing |
| count | 0 (process all slices) | Number of slices to convert |

# Log Files

*gen\_pdpfa.sh*, *satr*, *dder*, and *pdpfa* each produce their own log file(s), the contents of which are explained below. The names used below are the default names for the log files used by each program. The “XXX” represents the SSN number corresponding to that log file.

## satr

### satr\_log\_XXX.txt

Contains information about the CT image, atr, and labels produced for this SSN. See Appendix A: Example satr Log File for an example log file.

## dder

### dder\_log\_summary\_XXX.txt

Contains score information for this SSN, including information about all targets, labels, detections, incomplete detections, false alarms, and misses. See Appendix B: Example dder Summary Log File for an example log file.

### dder\_log\_false\_alarms\_XXX.xls

Tab-delimited log file that can be opened in Excel for filtering/sorting. Contains information about each false alarm produced by the ATR for this SSN, including the ATR label IDs and any targets or pseudo-targets that intersected each label, as well as information about any intersecting targets or pseudo-targets. The following table describes each field. See Appendix C: Example dder False Alarms Log File for an example log file.

| **Field Name** | **Description** |
| --- | --- |
| SSN | SSN of the scored image |
| FA\_Label\_ID | Label ID of false alarm |
| Intersecting\_Target\_ID | ID of intersecting target (if applicable) |
| Intersecting\_Target\_Form | Form (bulk or sheet) of intersecting target (if applicable) |
| Intersecting\_Target\_Subtype | Subtype (saline, clay, rubber, or powder) of intersecting target (if applicable) |
| Precision | Precision of intersecting target (if applicable) |
| Recall | Recall of intersecting target (if applicable) |

## pdpfa

### pdpfa\_log\_summary.txt

Contains summary score information for all specified SSNs, including:

1. PFA
2. Average number of false alarms per bags with at least one false alarm
3. PD based on type (target, pseudo-target, or both)
4. PD based on level of difficulty (low and high)
5. PD based on sub-type (clay, rubber, saline, and powder)
6. PD based on form (bulk and sheet)

See Appendix D: Example pdpfa Summary Log File for an example log file.

### pdpfa\_log\_detections.xls

Tab-delimited log file that can be opened in Excel for filtering/sorting. Contains information for each target and pseudo-target that was scored, including whether it was detected or missed. The following table describes each field. See Appendix E: Example pdpfa Detections Log File for an example log file.

| **Field Name** | **Description** |
| --- | --- |
| SSN | SSN of the image |
| Target ID | Target ID |
| Detected | 0 or 1, indicating that the target was missed or detected, respectively |
| Material Type | t=target, pt=pseudo-target |
| Material Subtype | saline, clay, rubber, or powder |
| Material Form | bulk or sheet |
| Difficulty | low or high |
| Mass [g] | Mass of target [g] |
| Volume [cc] | Volume of target (including container and contents) [cc] |
| Dim x [mm] | x dimension of target [mm] |
| Dim y [mm] | y dimension of target [mm] |
| Dim z [mm] | z dimension of target [mm] |
| Bbox-x-min | Minimum x-coordinate of target's bounding box |
| Bbox-x-max | Maximum x-coordinate of target's bounding box |
| Bbox-y-min | Minimum y-coordinate of target's bounding box |
| Bbox-y-max | Maximum y-coordinate of target's bounding box |
| Bbox-z-min | Minimum z-coordinate of target's bounding box |
| Bbox-z-max | Maximum z-coordinate of target's bounding box |
| Object db description | Description of target taken from object database |
| Packing db description | Description of target taken from packing database |

### pdpfa\_log\_pds.xls

Tab-delimited log file that can be opened in Excel for filtering/sorting. Contains grouped PD information based on level of difficulty, form, and sub-type. Also contains PFA and average number of false alarms per bag with at least one false alarm. This log file contains information about targets only (pseudo-targets are excluded). The following table describes each field. See Appendix F: Example pdpfa PD Log File for an example log file.

|  |  |
| --- | --- |
| **Field Name** | **Description** |
| Target Subtype or Form | Saline, Clay, Rubber, Bulk, Sheet, or All |
| Level of Difficulty | Low, High, or All |
| Num Targets | Number of targets in the specified grouping |
| Num Detected | Number of targets detected in the specified grouping |
| PD (targets only) [%] | PD for the specified grouping |
| Num Non-targets | Total number of non-targets |
| Num FAs | Total number of false alarms generated |
| PFA [%] | PFA |
| Num Scans with FAs | Number of scans that generated at least one false alarm |
| Avg Num FAs | Average number of false alarms per bags with at least one false alarm (calculated as [Num FAs] / [ Num Scans with FAs] ) |

### pdpfa\_log\_false\_alarms.xls

Tab-delimited log file that can be opened in Excel for filtering/sorting. Contains information about each false alarm produced by the ATR for all specified SSNs, including the ATR label IDs and any targets or pseudo-targets that may have intersected each label, as well as information about any intersecting targets or pseudo-targets. The following table describes each field. See Appendix G: Example pdpfa False Alarms Log File.

| **Field Name** | **Description** |
| --- | --- |
| SSN | SSN of the scored image |
| FA Label ID | Label ID of false alarm |
| Intersecting Target ID | ID of intersecting target (if applicable) |
| Intersecting Target Form | Form (bulk or sheet) of intersecting target (if applicable) |
| Intersecting Target Subtype | Subtype (saline, clay, rubber, or powder) of intersecting target (if applicable) |
| Precision | Precision of intersecting target (if applicable) |
| Recall | Recall of intersecting target (if applicable) |

## gen\_pdpfa.sh

### gen\_pdpfa\_log.txt

Contains information about *gen\_pdpfa.sh*, including command line options used and standard output from each call to the specified ATR, *dder*, and *pdpfa*. See Appendix H: Example of gen\_pdpfa.sh Summary Log File for an example log file.

## gtver

### gtver\_log\_XXX.txt

Contains information about *gtver*, including command line options used, standard output, and verification results. See Appendix I: Example of gtver Log FileAppendix H: Example of gen\_pdpfa.sh Summary Log File for an example log file

# References

[1] Rupcich, F. and Crawford, C. R., “ALERT ATR Project: Top-Level Technical Specifications,” Version 4, April 12, 2014.

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

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

# Revision History

|  |  |
| --- | --- |
| **Version** | **Changes** |
| 1 | Initial revision |
| 2 | Revised based on updates to gen\_pdpfa.sh and feedback from Carl Crawford |
| 3 | Added more detail |
| 4 | Revised sections and added synopses |
| 5 | Added more detail and additional tools. Revised based on feedback from Carl. Added references section. Removed terms and point to Top-Level Spec instead. |
| 6 | Added updates to gen\_pdpfa.sh. Filled in section for gtver and added gtver log file. |
| 7 | Indicated that false alarms can also be found in dder false alarm log file |

# Appendix A: Example satr Log File

[Performer] Carl Crawford, Csuptwo

[Date]: Mon Mar 24 21:21:25 2014

[Time]: Mon Mar 24 21:21:25 2014

[CT-name] /home/franco/to4/ct/I100.fits.gz

[CT-format] FITS

[CT-columns] 512

[CT-rows] 512

[CT-slices] 244

[CT-first] 1

[CT-count] 244

[CT-fov] (mm) 475.00

[CT-pixel] (mm) 0.93

[CT-slice-space] (mm) 1.50

[CT-offset] (MHU) 0

[CT-dimension-z] (mm) 366.00

[CT-mean] (MHU) 4.36

[CT-mass] (g) 351.96

[Label-name] /home/franco/to4/labels/A100.fits.gz

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

[OS] Linux

[Executable] satr

[Version] $Id: satr.c,v 1.4 2014/02/08 17:23:59 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] 244

[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) 366.00

[Voxels] 63832324

[Mass] (g) 168.14

[Volume] (cc) 82409.87

[Mean] (MHU) 2.09

[Standard-deviation] (MHU) 56.34

[Label-num] 1

[Label-id] 1

[Slice-first] 48

[Slice-last] 138

[Row-first] 178

[Row-last] 220

[Column-first] 132

[Column-last] 327

[Dimension-x] (mm) 181.84

[Dimension-y] (mm) 39.89

[Dimension-z] (mm) 136.50

[Voxels] 130812

[Mass] (g) 183.82

[Volume] (cc) 168.88

[Mean] (MHU) 1114.57

[Standard-deviation] (MHU) 59.36

# Appendix B: Example dder Summary Log File

**NOTE: Fields for which there is no information recorded in the object database are marked “None Reported”**

[Program-name] dder

[Version] 1.18

[Date] 05/10/14

[Time] 11:59:19

[Summary-log-file-name] /home/franco/to4/logs/v35/dder\_logs/dder\_log\_summary\_008.txt

[False-alarm-log-file-name] /home/franco/to4/logs/v35/dder\_logs/dder\_log\_false\_alarms\_008.xls

Summary

--------------------

[Scan-serial-number] 008

[GT-label-image-filename] /home/franco/to4/gt/G008.fits.gz

[ATR-label-image-filename] /home/franco/to4/labels/A008.fits.gz

[Num-targets] 2

[Target-ids-present] 6004 6002

[Num-target-detections] 1

[Target-ids-detected] 6002

[Num-target-misses] 1

[Target-ids-missed] 6004

[Num-pseudo-targets] 1

[Pseudo-target-ids-present] 6026

[Num-pseudo-target-detections] 0

[Num-pseudo-target-misses] 1

[Pseudo-target-ids-missed] 6026

[Num-atr-labels] 6

[ATR-label-ids] 1 2 3 4 5 6

[Num-false-alarms] 5

[False-alarm-label-ids] 6 5 4 3 1

Command Line Information

-----------------------

[Target-database-filename] /home/franco/to4/to4-tools/dbase/odb.csv

[Bag-database-filename] /home/franco/to4/to4-tools/dbase/pdb.csv

[GT-label-image-filename] /home/franco/to4/gt/G008.fits.gz

[GT-label-image-size (nrow ncol nslice)] [512 512 482]

[ATR-label-image-filename] /home/franco/to4/labels/A008.fits.gz

[ATR-label-image-size (nrow ncol nslice)] [512 512 482]

[Precision-bulk-target] 0.50

[Recall-bulk-target] 0.50

[Precision-sheet-target] 0.20

[Recall-sheet-target] 0.20

[Precision-bulk-pseduo-target] 0.50

[Recall-bulk-pseudo-target] 0.50

[Precision-sheet-pseudo-target] 0.20

[Recall-sheet-pseduo-target] 0.20

[Alpha] 0.00

Information for GT label image (targets and pseduo-targets)

-----------------------------------------------------------

[Number-of-targets] 2

[Target-num] 1

[Target-id] 6002

[Label-pixels] 199222

[Label-volume (cc)] 257.4

[Label-column-first] 249

[Label-column-last] 409

[Label-row-first] 257

[Label-row-last] 314

[Label-slice-first] 102

[Label-slice-last] 146

[Label-dimension-row (mm)] 52.9

[Label-dimension-col (mm)] 148.5

[Label-dimension-slice (mm)] 66.0

[Target-object-database-description] Breast Milk Bottle 5% Saline

[Target-material-form] bulk

[Target-material-subtype] saline

[Target-dimension-x (mm)] None Recorded

[Target-dimension-y (mm)] None Recorded

[Target-dimension-z (mm)] None Recorded

[Target-mass (g)] 253.0

[Target-volume (cc)] None Recorded

[Target-packing-database-description] saline

[Target-xmin] 251

[Target-xmax] 408

[Target-ymin] 255

[Target-ymax] 314

[Target-zmin] 102

[Target-zmax] 146

[Target-level-of-difficulty] low

[Target-location-code] cbb

[Target-orientation-code]

[Target-num] 2

[Target-id] 6004

[Label-pixels] 382579

[Label-volume (cc)] 494.2

[Label-column-first] 361

[Label-column-last] 443

[Label-row-first] 230

[Label-row-last] 375

[Label-slice-first] 137

[Label-slice-last] 190

[Label-dimension-row (mm)] 134.6

[Label-dimension-col (mm)] 76.1

[Label-dimension-slice (mm)] 79.5

[Target-object-database-description] Rubber Mallet

[Target-material-form] bulk

[Target-material-subtype] rubber

[Target-dimension-x (mm)] None Recorded

[Target-dimension-y (mm)] None Recorded

[Target-dimension-z (mm)] None Recorded

[Target-mass (g)] 1025.0

[Target-volume (cc)] None Recorded

[Target-packing-database-description] Rubber Mallet

[Target-xmin] 358

[Target-xmax] 443

[Target-ymin] 227

[Target-ymax] 374

[Target-zmin] 136

[Target-zmax] 191

[Target-level-of-difficulty] low

[Target-location-code] cac

[Target-orientation-code] z-

[Number-of-pseudo-targets] 1

[Pseudo-target-num] 1

[Pseudo-target-id] 6026

[Label-pixels] 161827

[Label-volume (cc)] 209.0

[Label-column-first] 217

[Label-column-last] 309

[Label-row-first] 306

[Label-row-last] 373

[Label-slice-first] 121

[Label-slice-last] 168

[Label-dimension-row (mm)] 62.2

[Label-dimension-col (mm)] 85.4

[Label-dimension-slice (mm)] 70.5

[Pseudo-target-material-form] bulk

[Pseudo-target-material-subtype] powder

[Pseudo-target-dimension-x (mm)] None Recorded

[Pseudo-target-dimension-y (mm)] None Recorded

[Pseudo-target-dimension-z (mm)] None Recorded

[Pseudo-target-mass (g)] 277.0

[Pseudo-target-volume (cc)] 250.0

[Pseudo-target-object-database-description] TA\_MH01 plastic bottle + powder

[Pseudo-target-xmin] 215

[Pseduo-target-xmax] 309

[Pseduo-target-ymin] 305

[Pseduo-target-ymax] 371

[Pseduo-target-zmin] 121

[Pseduo-target-zmax] 168

[Pseduo-target-level-of-difficulty] high

[Pseduo-target-location-code] bab

[Pseduo-target-orientation-code] x-

[Pseduo-target-packing-database-description] P, TA\_MH01

Information for ATR label image

------------------------------------

[Number-of-labels] 6

[Label-num] 1

[Label-id] 1

[Label-pixels] 377501

[Label-volume (cc)] 487.6

[Label-column-first] 90

[Label-column-last] 309

[Label-row-first] 334

[Label-row-last] 370

[Label-slice-first] 56

[Label-slice-last] 127

[Label-dimension-row (mm)] 33.4

[Label-dimension-col (mm)] 203.2

[Label-dimension-slice (mm)] 106.5

[Label-num] 2

[Label-id] 2

[Label-pixels] 103484

[Label-volume (cc)] 133.7

[Label-column-first] 252

[Label-column-last] 407

[Label-row-first] 260

[Label-row-last] 312

[Label-slice-first] 103

[Label-slice-last] 145

[Label-dimension-row (mm)] 48.3

[Label-dimension-col (mm)] 143.8

[Label-dimension-slice (mm)] 63.0

[Label-num] 3

[Label-id] 3

[Label-pixels] 64612

[Label-volume (cc)] 83.5

[Label-column-first] 219

[Label-column-last] 307

[Label-row-first] 308

[Label-row-last] 369

[Label-slice-first] 123

[Label-slice-last] 166

[Label-dimension-row (mm)] 56.6

[Label-dimension-col (mm)] 81.7

[Label-dimension-slice (mm)] 64.5

[Label-num] 4

[Label-id] 4

[Label-pixels] 111611

[Label-volume (cc)] 144.2

[Label-column-first] 361

[Label-column-last] 438

[Label-row-first] 241

[Label-row-last] 369

[Label-slice-first] 142

[Label-slice-last] 187

[Label-dimension-row (mm)] 118.8

[Label-dimension-col (mm)] 71.5

[Label-dimension-slice (mm)] 67.5

[Label-num] 5

[Label-id] 5

[Label-pixels] 42787

[Label-volume (cc)] 55.3

[Label-column-first] 117

[Label-column-last] 252

[Label-row-first] 363

[Label-row-last] 390

[Label-slice-first] 202

[Label-slice-last] 286

[Label-dimension-row (mm)] 25.1

[Label-dimension-col (mm)] 125.3

[Label-dimension-slice (mm)] 126.0

[Label-num] 6

[Label-id] 6

[Label-pixels] 122608

[Label-volume (cc)] 158.4

[Label-column-first] 160

[Label-column-last] 351

[Label-row-first] 307

[Label-row-last] 335

[Label-slice-first] 209

[Label-slice-last] 367

[Label-dimension-row (mm)] 26.0

[Label-dimension-col (mm)] 177.2

[Label-dimension-slice (mm)] 237.0

Score Summary

--------------------

[Num-target-detections] 1

[Num-target-misses] 1

[Num-pseudo-target-detections] 0

[Num-pseudo-target-misses] 1

[Num-false-alarms] 5

[Num-incomplete-detections] 2

Detections (Targets)

----------------------

[Detection-number] 1 of 1

[Target-id] 6002

[Target-material-form] bulk

[Target-material-subtype] saline

[ATR-label-id-number] 1 of 1

[ATR-label-id] 2

[Precision] 1.00

[Recall] 0.52

Detections (Pseudo-targets)

----------------------------

NONE

False Alarms

-----------------

NOTE: Intersecting GT labels include both targets AND pseudo-targets.

NOTE: Intersecting GT labels reported only if alpha\*p, alpha\*r is met, AND GT and ATR labels intersect by at least one pixel.

[False-alarm-number] 1 of 5

[ATR-label-id] 6

[Num-intersecting-gt-labels] 0

[False-alarm-number] 2 of 5

[ATR-label-id] 5

[Num-intersecting-gt-labels] 0

[False-alarm-number] 3 of 5

[ATR-label-id] 4

[Num-intersecting-gt-labels] 1

[Intersecting-target-id-number] 1 of 1

[Intersecting-target-id] 6004

[Target-material-form] bulk

[Target-material-subtype] rubber

[Precision] 1.00

[Recall] 0.29

[False-alarm-number] 4 of 5

[ATR-label-id] 3

[Num-intersecting-gt-labels] 1

[Intersecting-target-id-number] 1 of 1

[Intersecting-target-id] 6026

[Target-material-form] bulk

[Target-material-subtype] powder

[Precision] 1.00

[Recall] 0.40

[False-alarm-number] 5 of 5

[ATR-label-id] 1

[Num-intersecting-gt-labels] 0

Misses (Targets)

-------------------

[Miss-number] 1 of 1

[Target-id] 6004

[Target-material-form] bulk

[Target-material-subtype] rubber

[Num-intersecting-atr-labels] 2

[Intersecting-atr-label-id-number] 1 of 2

[Intersecting-atr-label-id] 2

[Precision] 0.00

[Recall] 0.00

[Intersecting-atr-label-id-number] 2 of 2

[Intersecting-atr-label-id] 4

[Precision] 1.00

[Recall] 0.29

Misses (Pseudo-targets)

------------------------

[Miss-number] 1 of 1

[Pseudo-target-id] 6026

[Pseudo-target-material-form] bulk

[Pseudo-target-material-subtype] powder

[Num-intersecting-atr-labels] 1

[Intersecting-atr-label-id-number] 1 of 1

[Intersecting-atr-label-id] 3

[Precision] 1.00

[Recall] 0.40

# Appendix C: Example dder False Alarms Log File

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **SSN** | **ATR\_Label\_ID** | **Intersecting\_Target\_ID** | **Intersecting\_Target\_Form** | **Intersecting\_Target\_Subtype** | **Precision** | **Recall** |
| 8 | 6 | NA | NA | NA | NA | NA |
| 8 | 5 | NA | NA | NA | NA | NA |
| 8 | 4 | 6004 | bulk | rubber | 1 | 0.29 |
| 8 | 3 | 6026 | bulk | powder | 1 | 0.4 |
| 8 | 1 | NA | NA | NA | NA | NA |

# Appendix D: Example pdpfa Summary Log File

[Program-name] pdpfa

[Version] 1.4

[Date] 05/10/14

[Time] 12:10:06

Command Line Information

-----------------------

[Input-log-list-filename] /home/franco/to4/logs/v35/gen\_pdpfa\_list.txt

[Object-database-filename] /home/franco/to4/to4-tools/dbase/odb.csv

[Packing-database-filename] /home/franco/to4/to4-tools/dbase/pdb.csv

[Summary-log-filename] /home/franco/to4/logs/v35/pdpfa\_logs/pdpfa\_log\_summary.txt

[Detection-log-filename] /home/franco/to4/logs/v35/pdpfa\_logs/pdpfa\_log\_detections.xls

[False-alarm-log-filename] /home/franco/to4/logs/v35/pdpfa\_logs/pdpfa\_log\_false\_alarms.xls

NOTE: See [Input-log-list-filename], [Detection-log-filename], and/or [False-alarm-log-filename] files for ist of SSNs used

NOTE: PD = (# detections)/(# targets)

NOTE: PFA = (total # false alarms)/(total # non-targets)

NOTE: Average number false alarms = (total # false alarms)/(total # scans with at least one false alarm)

[Total-num-scans] 188

[Total-num-objects] 1851

[Total-num-non-targets] 1366

[Total-num-targets-and-pseudo-targets] 485

[Total-num-targets] 412

[Total-num-pseduo-targets] 73

[PFA] 0.24

[Average-num-false-alarms] 2.36

PD for targets only

-------------------

[PD-targets-overall] 0.76

[PD-targets-low-difficulty] 0.79

[PD-targets-high-difficulty] 0.74

[PD-targets-clay] 0.78

[PD-targets-rubber] 0.86

[PD-targets-saline] 0.62

[PD-targets-bulk] 0.69

[PD-targets-sheet] 0.89

PD for pseudo-targets only

---------------------------

[PD-pseudo-targets-overall] 0.34

[PD-pseudo-targets-low-difficulty] N/A

[PD-pseudo-targets-high-difficulty] 0.34

[PD-pseudo-targets-clay] 0.90

[PD-pseudo-targets-rubber] 0.30

[PD-pseudo-targets-saline] 0.63

[PD-pseudo-targets-powder] 0.03

[PD-pseudo-targets-bulk] 0.35

[PD-pseudo-targets-sheet] 0.30

PD for targets AND pseudo-targets

-----------------------------------

[PD-targets-and-pseudo-targets-overall] 0.69

[PD-targets-and-pseudo-targets-low-difficulty] 0.79

[PD-targets-and-pseudo-targets-high-difficulty] 0.66

[PD-targets-and-pseudo-targets-clay] 0.79

[PD-targets-and-pseudo-targets-rubber] 0.83

[PD-targets-and-pseudo-targets-saline] 0.62

[PD-targets-and-pseudo-targets-powder] 0.03

[PD-targets-and-pseudo-targets-bulk] 0.63

[PD-targets-and-pseudo-targets-sheet] 0.85

# Appendix E: Example pdpfa Detections Log File

**NOTE: Fields for which there is no information recorded in the object database are marked “None Reported”**

| **SSN** | **Target ID** | **Detected** | **Material Type** | **Material Subtype** | **Material Form** | **Difficulty** | **Mass [g]** | **Volume [cc]** | **Dim x [mm]** | **Dim y [mm]** | **Dim z [mm]** | **Bbox x-min** | **Bbox x-max** | **Bbox y-min** | **Bbox y-max** | **Bbox z-min** | **Bbox z-max** | **Object db description** | **Packing db description** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 4 | 6004 | 0 | t | rubber | bulk | low | 1025 | None Recorded | None Recorded | None Recorded | None Recorded | 317 | 410 | 198 | 351 | 25 | 78 | Rubber Mallet | Rubber mallet |
| 4 | 6002 | 1 | t | saline | bulk | low | 253 | None Recorded | None Recorded | None Recorded | None Recorded | 126 | 200 | 243 | 343 | 188 | 231 | Breast Milk Bottle 5% Saline | Saline |
| 5 | 6004 | 0 | t | rubber | bulk | low | 1025 | None Recorded | None Recorded | None Recorded | None Recorded | 127 | 211 | 201 | 349 | 210 | 263 | Rubber Mallet | Rubber Mallet |
| 5 | 6002 | 0 | t | saline | bulk | low | 253 | None Recorded | None Recorded | None Recorded | None Recorded | 209 | 280 | 246 | 346 | 224 | 267 | Breast Milk Bottle 5% Saline | saline |
| 6 | 7006 | 0 | t | saline | bulk | high | 0 | None Recorded | None Recorded | None Recorded | None Recorded | 179 | 338 | 271 | 341 | 40 | 142 | Merged - saline in bottle and saline in bag | (merged) saline |
| 6 | 7007 | 1 | t | rubber | sheet | high | 0 | 0 | None Recorded | None Recorded | None Recorded | 115 | 388 | 170 | 353 | 30 | 244 | Merged - two rubber sheets | (merged) rubber sheet |
| 7 | 7007 | 1 | t | rubber | sheet | high | 0 | 0 | None Recorded | None Recorded | None Recorded | 110 | 396 | 231 | 351 | 29 | 241 | Merged - two rubber sheets | (merged) rubber sheet |
| 7 | 6011 | 0 | t | saline | bulk | high | 285 | 0 | None Recorded | None Recorded | None Recorded | 148 | 217 | 276 | 328 | 29 | 124 | Breast Milk bottle 10% Saline | saline |
| 7 | 6012 | 0 | t | saline | bulk | high | 285 | 0 | 0 | 0 | 0 | 137 | 239 | 227 | 288 | 27 | 130 | Breast milk bag 10% Saline | saline |

# Appendix F: Example pdpfa PD Log File

| **Target Type** | **Target Subtype or Form** | **Level of Difficulty** | **Num Targets** | **Num Detected** | **PD [%]** |
| --- | --- | --- | --- | --- | --- |
| All | All | All | 485 | 337 | 69.5 |
| All | Clay | All | 121 | 96 | 79.3 |
| All | Rubber | All | 173 | 143 | 82.7 |
| All | Saline | All | 157 | 97 | 61.8 |
| All | Powder | All | 34 | 1 | 2.9 |
| All | Bulk | All | 338 | 212 | 62.7 |
| All | Sheet | All | 147 | 125 | 85 |
| All | All | High | 376 | 248 | 66 |
| All | Clay | High | 92 | 71 | 77.2 |
| All | Rubber | High | 134 | 109 | 81.3 |
| All | Saline | High | 116 | 67 | 57.8 |
| All | Powder | High | 34 | 1 | 2.9 |
| All | Bulk | High | 254 | 147 | 57.9 |
| All | Sheet | High | 122 | 101 | 82.8 |
| Target | All | All | 412 | 312 | 75.7 |
| Target | Clay | All | 111 | 87 | 78.4 |
| Target | Rubber | All | 163 | 140 | 85.9 |
| Target | Saline | All | 138 | 85 | 61.6 |
| Target | Bulk | All | 275 | 190 | 69.1 |
| Target | Sheet | All | 137 | 122 | 89.1 |
| Target | All | Low | 96 | 76 | 79.2 |
| Target | Clay | Low | 29 | 25 | 86.2 |
| Target | Rubber | Low | 28 | 23 | 82.1 |
| Target | Saline | Low | 39 | 28 | 71.8 |
| Target | Bulk | Low | 71 | 52 | 73.2 |
| Target | Sheet | Low | 25 | 24 | 96 |
| Target | All | High | 303 | 223 | 73.6 |
| Target | Clay | High | 82 | 62 | 75.6 |
| Target | Rubber | High | 124 | 106 | 85.5 |
| Target | Saline | High | 97 | 55 | 56.7 |
| Target | Bulk | High | 191 | 125 | 65.4 |
| Target | Sheet | High | 112 | 98 | 87.5 |
| Pseudo-target | All | High | 73 | 25 | 34.2 |
| Pseudo-target | Clay | High | 10 | 9 | 90 |
| Pseudo-target | Rubber | High | 10 | 3 | 30 |
| Pseudo-target | Saline | High | 19 | 12 | 63.2 |
| Pseudo-target | Powder | High | 34 | 1 | 2.9 |
| Pseudo-target | Bulk | High | 63 | 22 | 34.9 |
| Pseudo-target | Sheet | High | 10 | 3 | 30 |
|  |  |  |  |  |  |
| **Num Non-targets** | **Num FAs** | **PFA [%]** |  |  |  |
| 1366 | 330 | 24.2 |  |  |  |
|  |  |  |  |  |  |
| **Num FAs**  | **Num Scans with FAs** | **Avg Num FAs** |  |  |  |
| 330 | 140 | 2.36 |  |  |  |

# Appendix G: Example pdpfa False Alarms Log File

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **SSN** | **ATR Label ID** | **Intersecting Target ID** | **Intersecting Target Form** | **Intersecting Target Subtype** | **Intersecting Target Precision** | **Intersecting Target Recall** |
| 4 | 1 | NA | NA | NA | NA | NA |
| 5 | 1 | 6004 | bulk | rubber | 1 | 0.28 |
| 6 | 4 | NA | NA | NA | NA | NA |
| 6 | 3 | 7006 | bulk | saline | 1 | 0.39 |
| 6 | 2 | 7006 | bulk | saline | 0.95 | 0.31 |
| 7 | 3 | NA | NA | NA | NA | NA |
| 7 | 2 | NA | NA | NA | NA | NA |

# Appendix H: Example of gen\_pdpfa.sh Summary Log File

[Program-name] gen\_pdpfa.sh

[Timestamp] Mon Mar 24 20:58:48 CDT 2014

Command Line Information

------------------------

[CT-dir] /home/franco/to4/ct

[GT-dir] /home/franco/to4/gt

[Labels-dir] /home/franco/to4/labels

[Logs-dir] /home/franco/to4/logs

[Label-image-prefix] A

[ATR-binary] /home/franco/to4/to4-tools/satr/satr

[SSN-list-filename]

NOTE: The remainder of this logfile is output from the atr, *dder*, and *pdpfa* programs

# Appendix I: Example of gtver Log File

[Program-name] gtver

[Version] 1.2

[Date] 05/10/14

[Time] 11:41:22

Command Line Information

-----------------------

[Input-CT-image-filename]: /home/franco/to4/ct/I004.fits.gz

[Input-GT-image-filename]: /home/franco/to4/gt/to\_verify/G004.fits.gz

[Input-odb-filename]: /home/franco/to4/to4-tools/dbase/odb.csv

[Input-pdb-filename]: /home/franco/to4/to4-tools/dbase/pdb.csv

[Output-log-filename]: /home/franco/to4/gt/gtver\_logs/gtver\_log\_004.txt

Verification Output

-----------------------

NOTE: This program verifies targets AND pseudo-targets

--- IMAGE SIZE VERIFICATION ---

CT image [nrow ncol nslice]: [512 512 304]

GT image [nrow ncol nslice]: [512 512 304]

--- IMAGE SIZE VERIFICATION: PASSED! ---

--- GT LABEL ID VERIFICATION ---

GT label IDs match target IDs from database for this scan.

Target/Label IDs for this image:

6004

6002

--- GT LABEL ID VERIFICATION: PASSED! ---

--- TARGET MASS VERIFICATION ---

Target/label ID: 6004

Mass from database [g]: 1025.0

Mass calculated [g]: 1069.7

Mass witin spec?: YES

Target/label ID: 6002

Mass from database [g]: 253.0

Mass calculated [g]: 265.6

Mass witin spec?: YES

--- TARGET MASS VERIFICATION: PASSED! ---

--- TARGET BOUNDING BOX VERIFICATION ---

Target/label ID: 6004

Calculated precision: 0.89

Calculated recall: 0.99

Precision/recall witin spec?: YES

Target/label ID: 6002

Calculated precision: 0.95

Calculated recall: 0.98

Precision/recall witin spec?: YES

--- TARGET BOUNDING BOX VERIFICATION: PASSED! ---

[Verification-summary]: PASSED