caBIG™ cancer Biomedical Informatics Grid ™

An Initiative of the National Cancer Institute

Algorithm Validation Toolkit (AVT)

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The Problem to be Solved

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- **Automated and semi-automated image analysis algorithms are being developed and promulgated to support lesion**
  - detection and characterization
  - size quantification and change over time
- **Also image analysis for supporting functions**
  - registration and spatial transformation
- **For a broad range of applications**
  - including clinical use and for clinical trials
- **How does one "validate" their correctness ?**
  - adequately
  - efficiently

The Landscape

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- **Many ongoing and new efforts to collect data, establish "truth" and define "methodology"**
- **LIDC**
  - Lung Image Database Consortium
- **RIDER**
  - Reference Image Database to Evaluate Response
  - phantom images (FDA)
- **NIST Biochange 2008**
  - change measurement algorithm evaluation
- **MICCAI**
  - Segmentation challenge (liver, brain, coronary)
- **QIBA**
  - Quantitative Imaging Biomarkers Alliance (vol CT, DCE-MR, PET)
- **…**

AVT – One Component of a Solution

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- A “toolkit” of software components, for

- Accessing a collection of images
- Gathering the “truth”
- Gathering measurements, e.g., of “change”
- Applying statistical methods to assessment of accuracy, precision, repeatability

- Persisting and making accessible data, measurements and results
- Applicable to human, semi-automated and automated measurement techniques

AVT – Example Use Case

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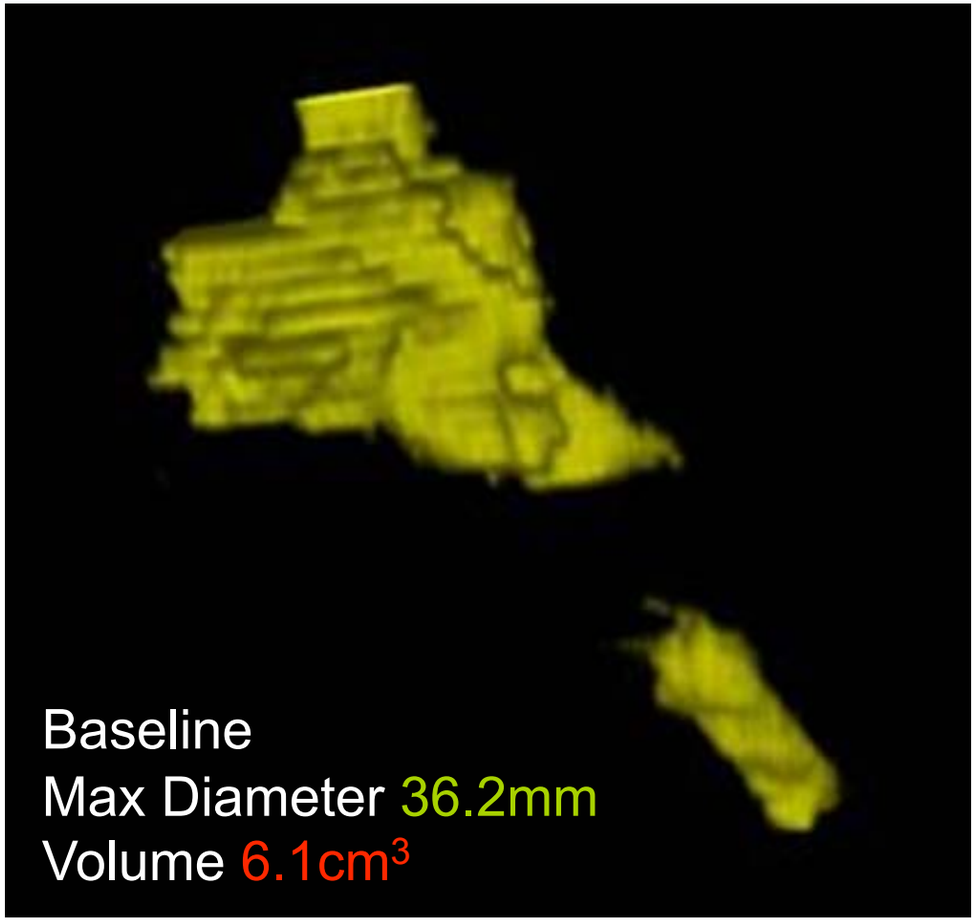

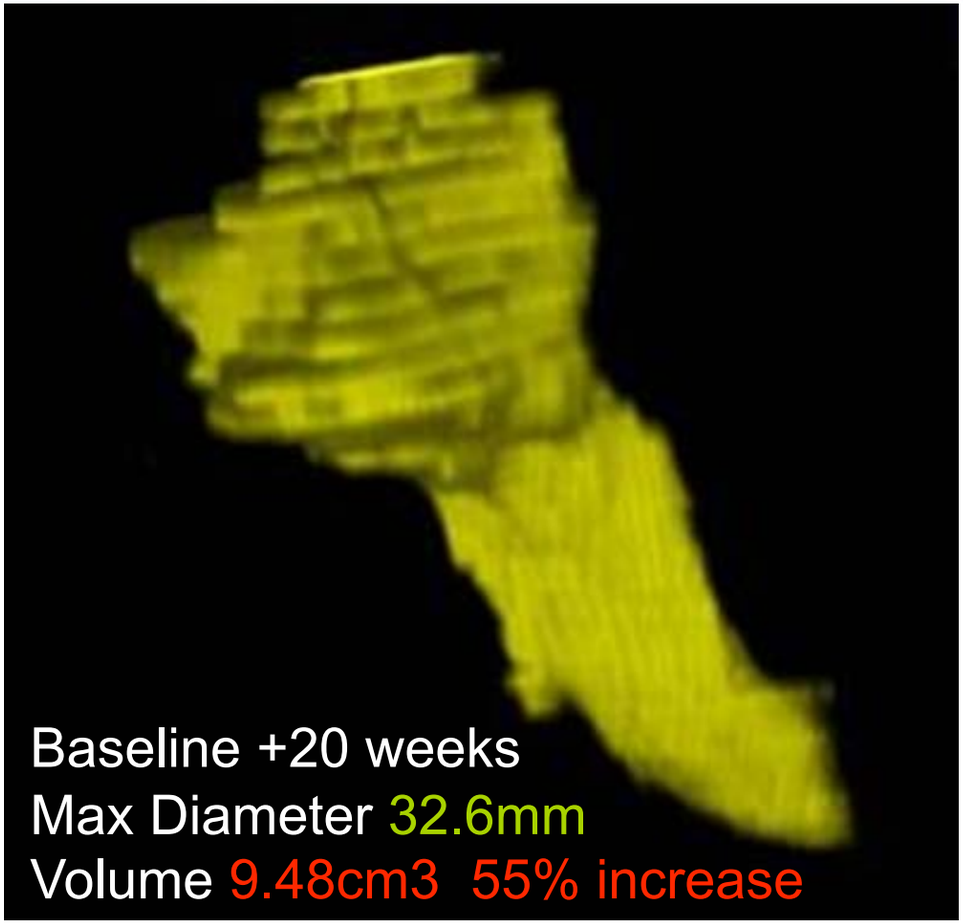

- **Validation of measurement of change in lesion size over time**
- **Ground truth at multiple time points (manual + consensus panel)**
- **Automated detection, measurement of size, computation of change**
- **MVT analysis of detection (ROC), consistency (Bland-Altman)**
- **Successive iterations of experiment with improvement of algorithm**

AVT – Supports Broad Range of Use Cases

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- **Essentially limited only by**
  - Data types
    - images, annotations, vocabulary
  - Source of truth
    - Image Analysis component
    - alternative source (convert to AIM and import)
  - Interfaces to algorithm under test
    - persistence method and form of output
    - orchestration of execution
  - Range of statistical methods provided by R in MVT
  - AVT support for orchestration of experimental paradigm

AVT – Use Case Variants

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- **Modality**
  - single (CT), multiple (e.g., CT/PET, multispectral MR)
- **Acquisition**
  - One, multiple (“coffee break”)
- **Pre-processing**
  - registration, segmentation, deformation, detection, propagation
- **Annotation**
  - manual, semi-automated, automated
- **Readers**
  - one, multiple, adjudicated, inter- and intra- variability
- **Measurement**
  - size (RECIST, volume), function (SUV)
  - change (two time points, multiple time points)

AVT – Role of First Users

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- **Strong emphasis on feedback from users throughout project**
- **Evaluation and testing of use-case model**
  - walk through of use-cases
- **Evaluation and testing of early deliverables**
  - various modalities, measurements and paradigms
  - existing and new public image data sets
  - existing and new “ground truth” annotations
- **Users involved**
  - ACRIN, RadPharm, OHSU, UCLA, FDA CDRH, U Chicago, Cornell, U Michigan

AVT – Extend Existing Infrastructure

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- **Requirement to re-use and integrate existing tools**
  - XIP (eXtensible Imaging Platform)
  - caGRID accessibility (grid data service)
  - National Cancer Image Archive (NCIA)
  - DICOM images
  - AIM annotations
  - caBIG vocabulary (Common Data Elements (CDE))
  - R statistical package
- **Open source**
  - components
  - deliverables

AVT – Initial Concept of Operations

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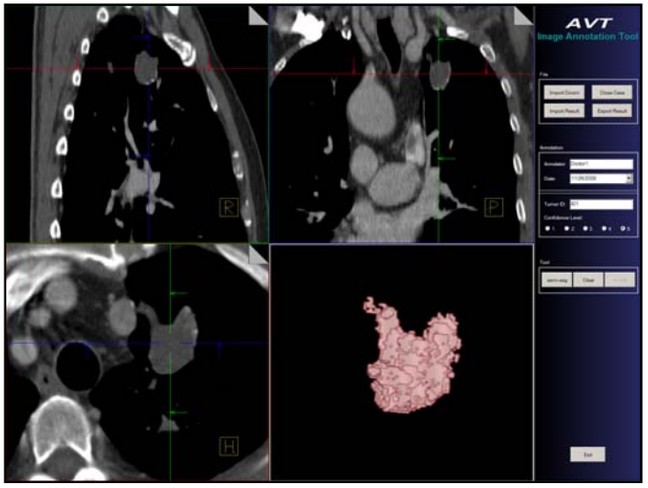
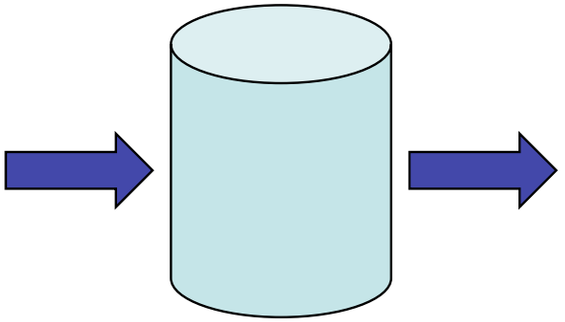
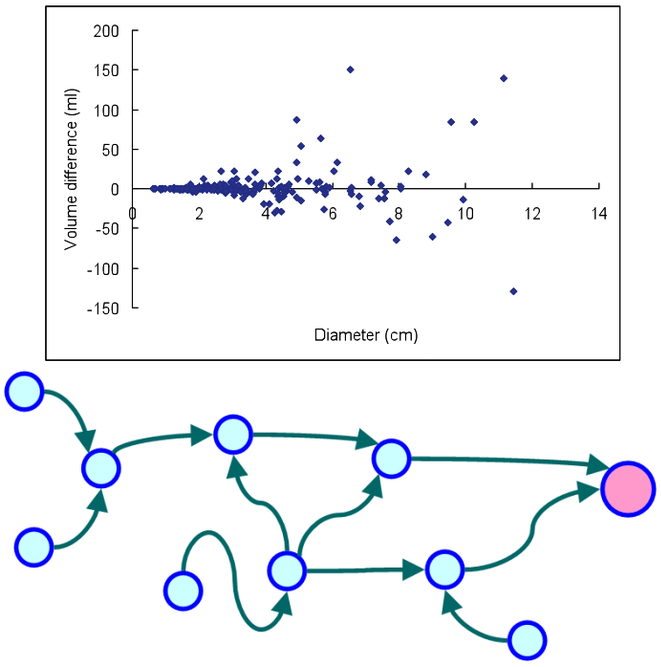
IA: Image Analysis



AD: Assessment Database



MVT: Measurement Variability Tool



- IA used to perform measurements and encode as AIM
- AD captures AIM & additional image & provenance data
- MVT computes measurement statistics and correlations between metrics and outcomes

AVT – Components

- **Image Analysis (IA):** An image analysis component that displays images and permits features to be identified, measured and marked and the results exported in the form of AIM data structures;

- **Assessment Database (AD):** An assessment database schema for storing the AIM objects and results produced by the first component (or equivalent functions);

- **Measurement Variability Tool (MVT):** Tools to extract measurements placed in the assessment database and compute their variability as a function of such variables as intra- and inter-rater, scanner, exam type, processing, time, software used.

AVT – Architecture Overview

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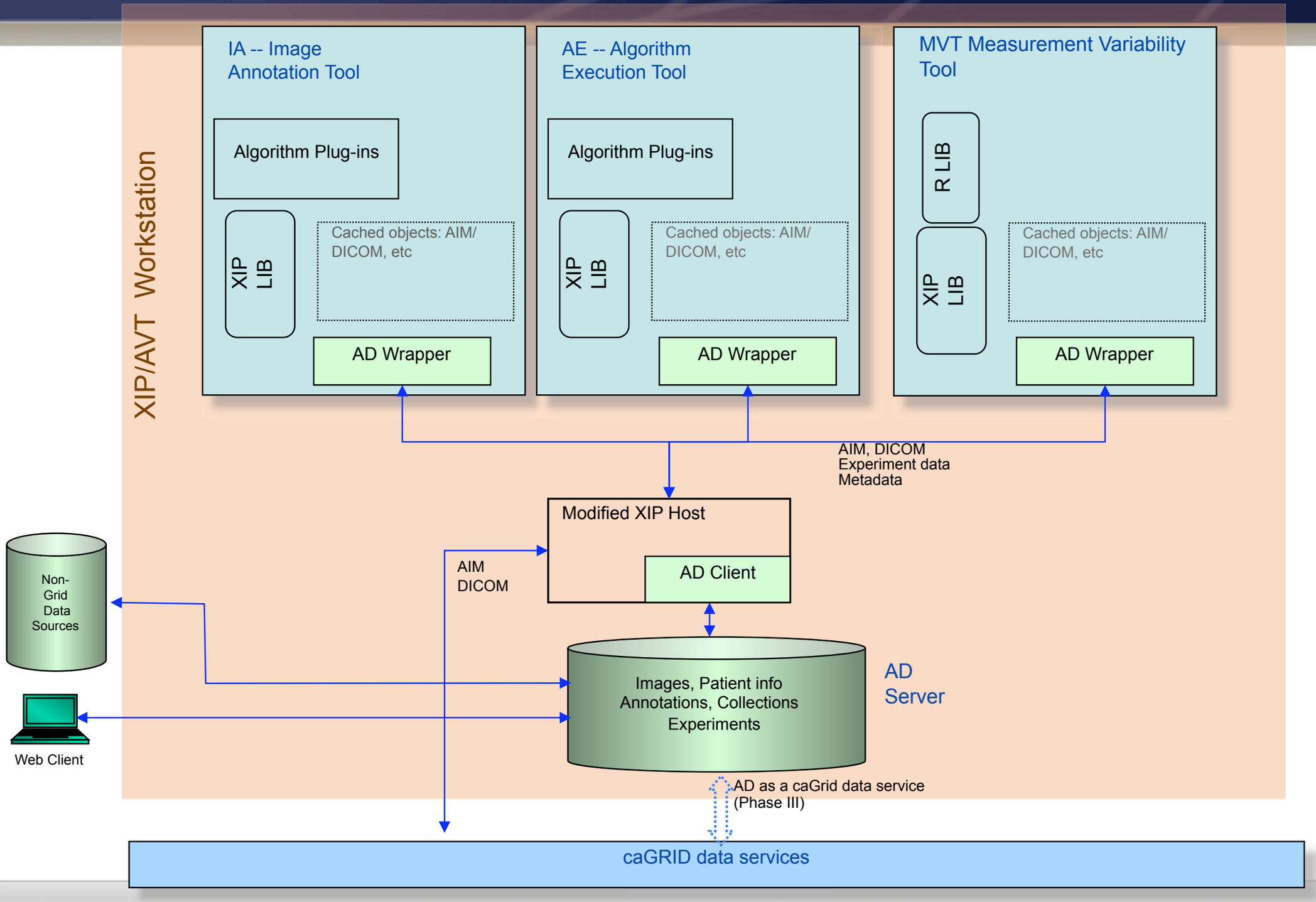
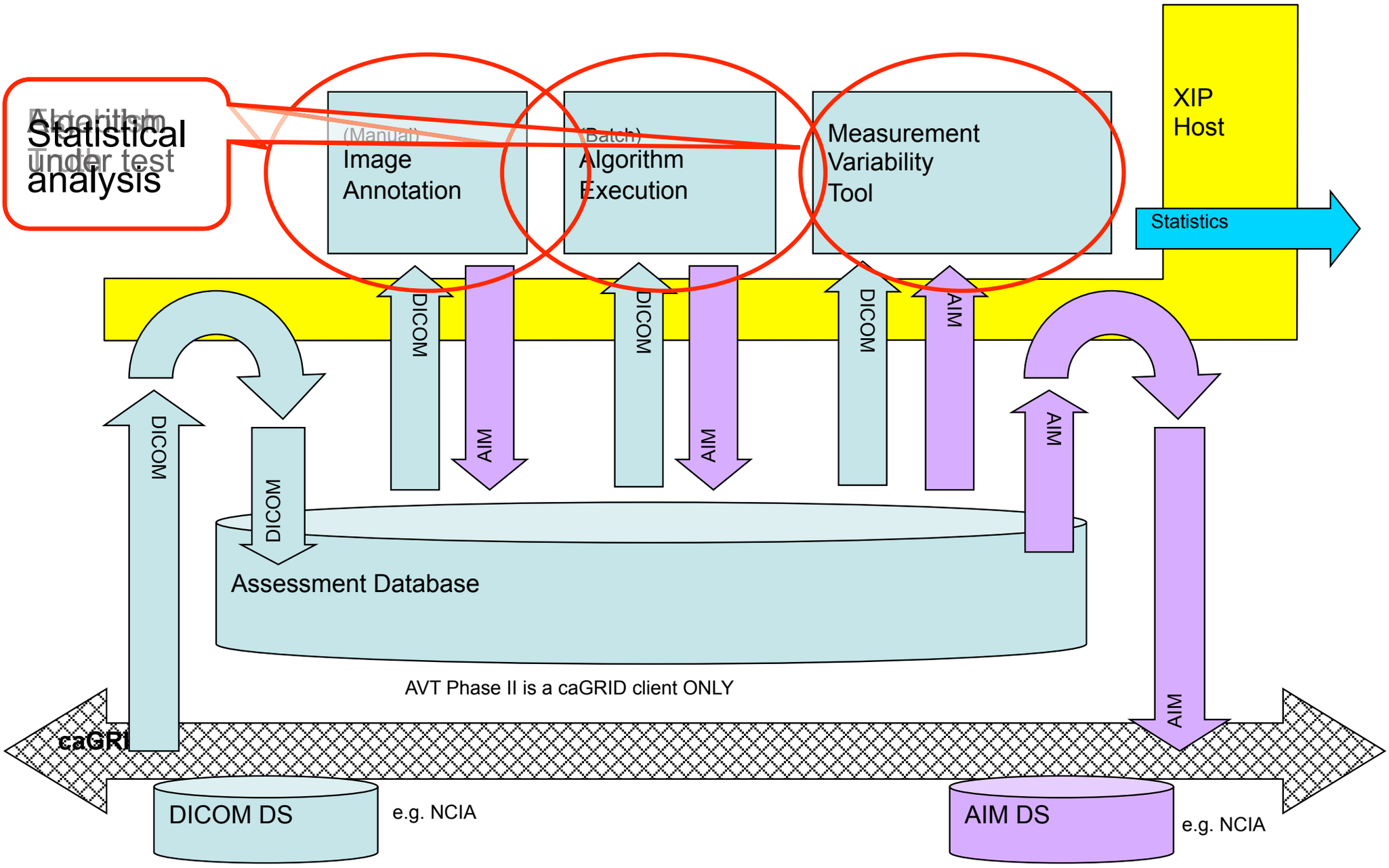
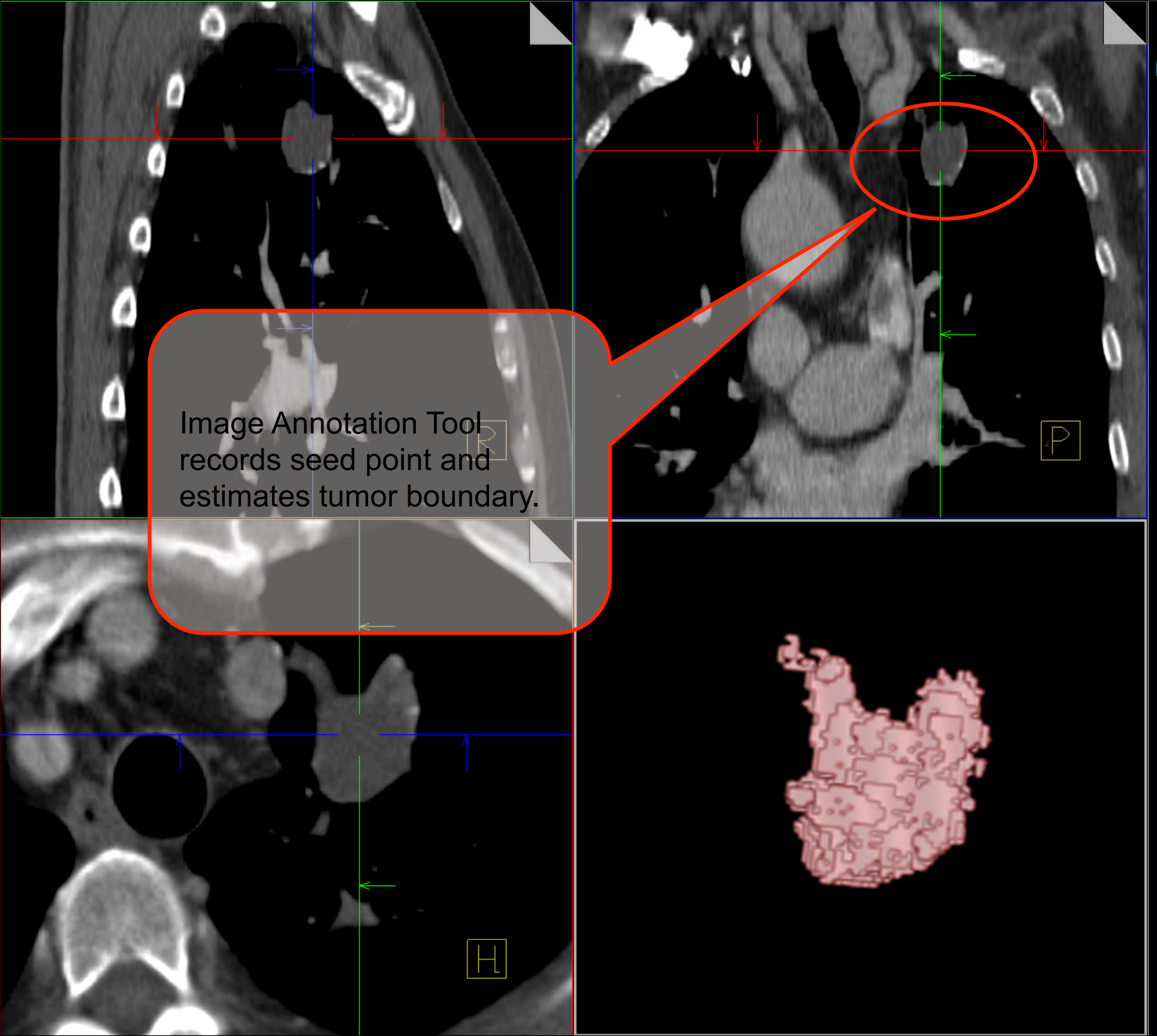


AVT – Data Flow




AVT
Image Annotation Tool
File
Import Dicom
Close Case
Import Result
Export Result
Annotation
Annotator:
Doctor1
Date:
11/26/2008
Tumor ID:
ID1
Confidence Level:
1
2
3
4
5
Tool
semi-seg
Clear
modify
Exit
Image Annotation Tool records seed point and estimates tumor boundary.
R
P
H

AVT – MVT Component

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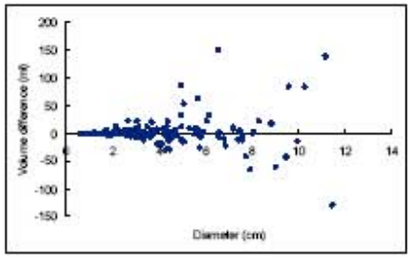
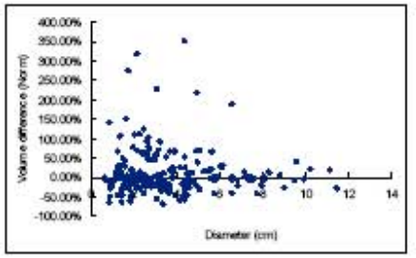
Dependency of the Prototype on Lesion Size & Slice Thickness

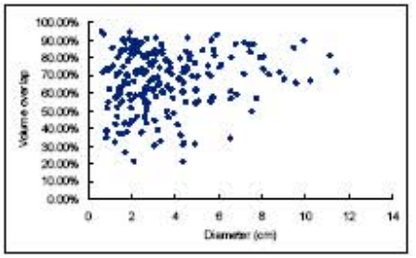
- Linear regression analysis on performance dependency on lesion size



(a) volume difference



(b) normalized volume difference

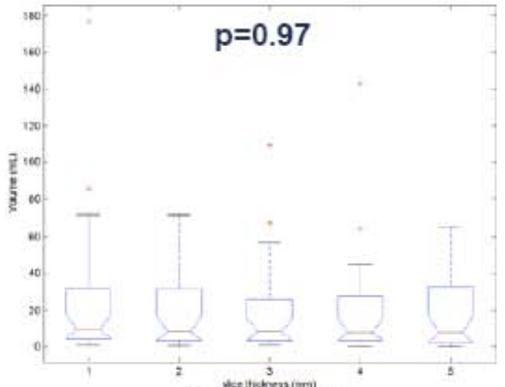


(c) volume overlap

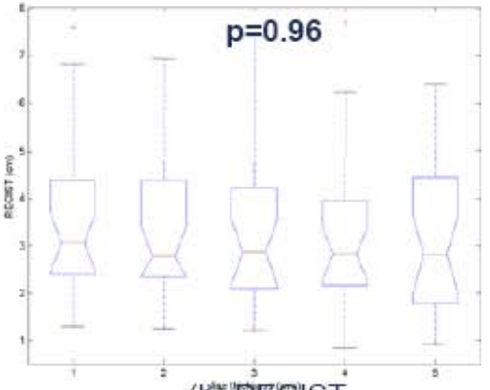
The algorithm is relatively robust to lesion size, demonstrated by the small coefficient of determination in the linear regression analysis

- Non-parametric analysis on slice thickness dependency

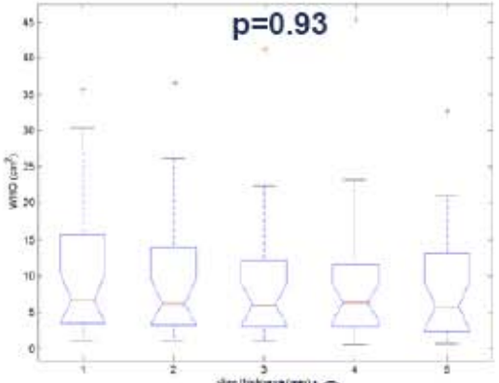
Due to the non-Gaussian distribution and variance inhomogeneity, Kruskal-Wallis test was applied to study the performance variation among different slice thickness



(a) volume



(b) RECIST



(c) WHO

Kruskal-Wallis analysis (non parametric testing) showed the algorithm is relatively robust to slice thickness.

File Edit Help

History Report | Close

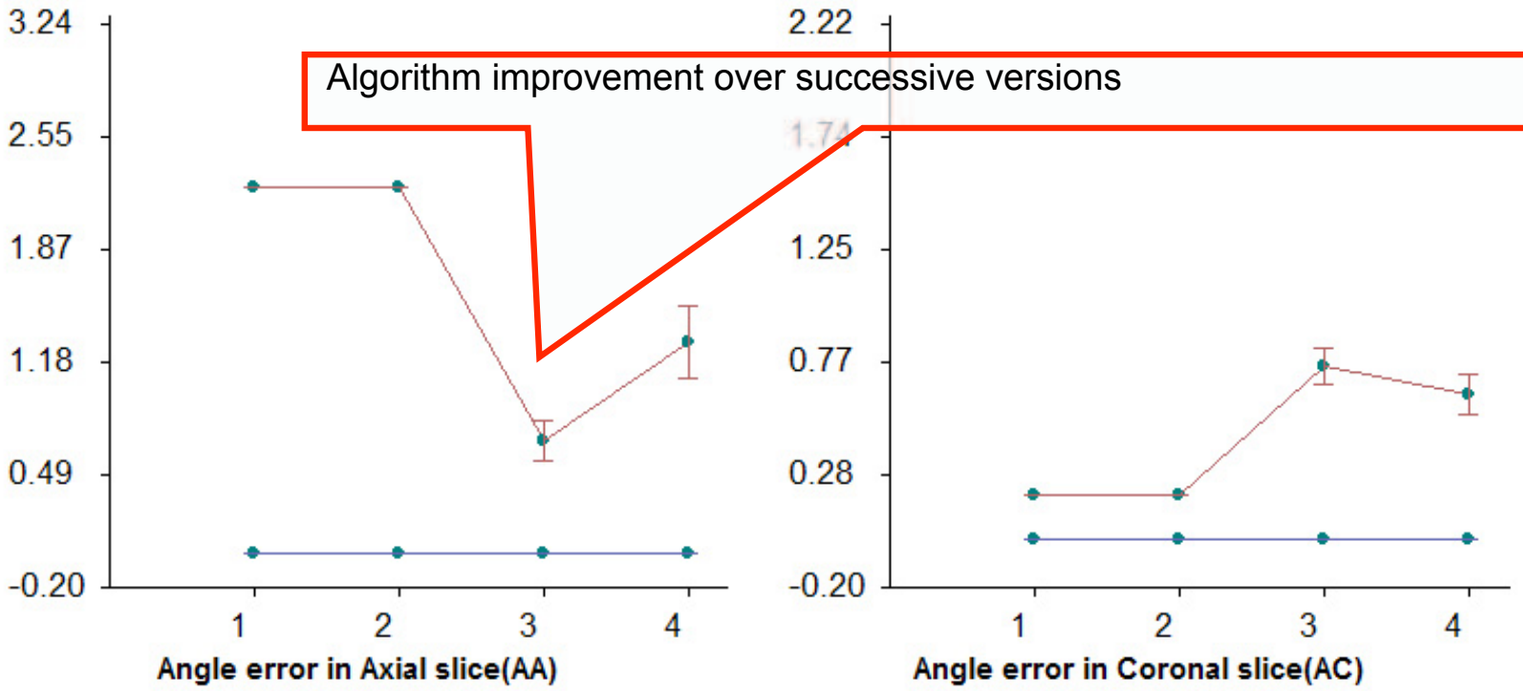
History Report Analysis

Statistical Summary:

Mean Value Table:

		AA01	AC01	AA02	AC02	AA12	AC12
1	26-11-2008□14:40	2.24	0.19	2.24	1.17	0.00	0.98
2	26-11-2008□14:39	2.24	0.19	2.24	1.17	0.00	0.98
3	15-10-2008□17:14	0.69	0.75	0.53	0.75	0.71	0.75
4	08-09-2008□10:04	1.30	0.63	0.93	0.87	0.48	1.22

Metrics Curve:



Algorithm improvement over successive versions

Note:
stands for the comparison between auto results and ground truth #1.
stands for the comparison between auto results and ground truth #2.
stands for the comparison between ground truth #1 and #2.

CMIV
SIEMENS CORPORATE TECHNOLOGY

File

Import Data | Anonymize Data | Import Result | Clear Result

Accuracy | Reproducibility

Metrics Selection
- [x] Angular error of Mid-sag in coronal
- [x] Angular error of Mid-sag in axial

Statistics Selection
- [x] Mean [x] SD

Outlier Selection

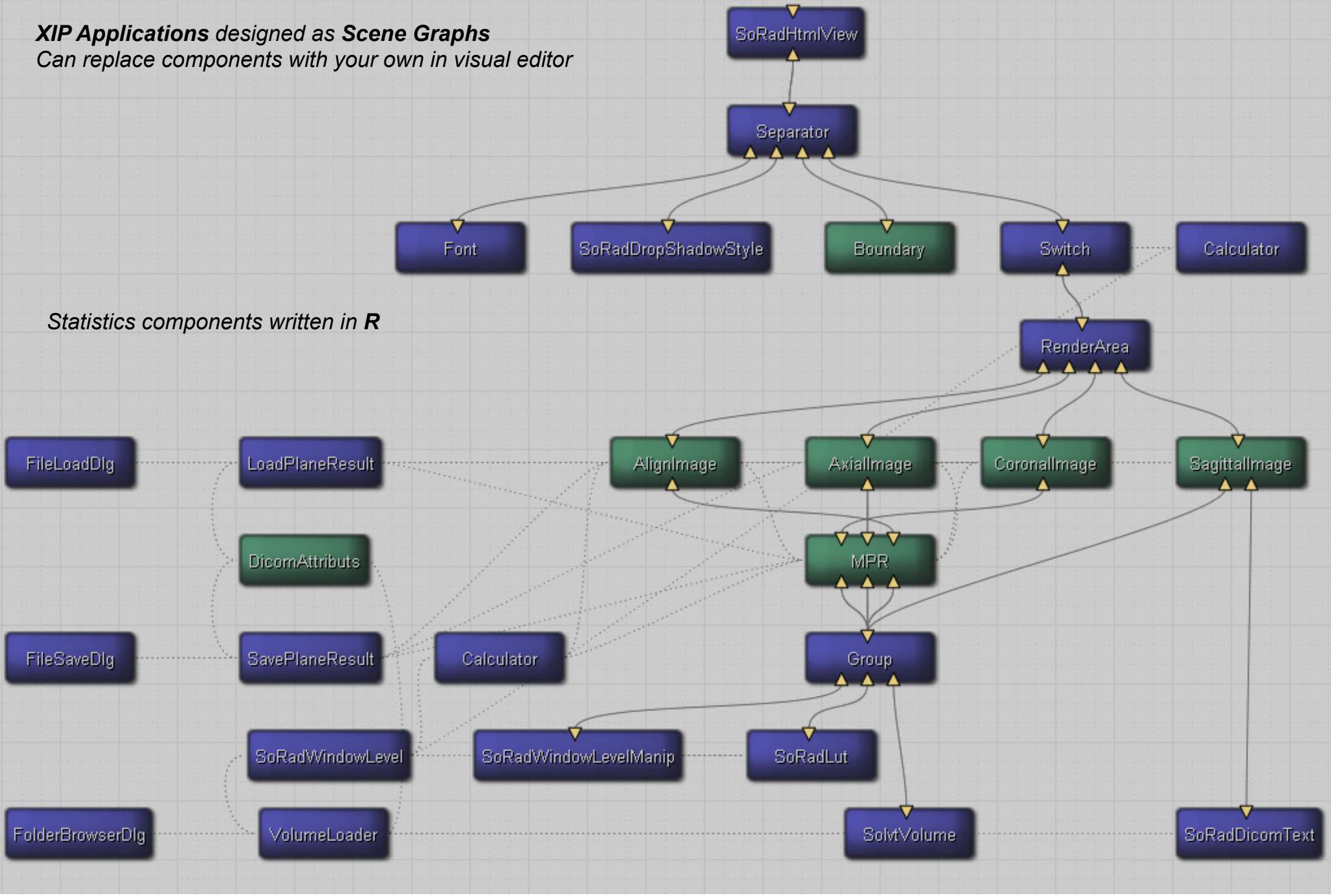
Angular error of Mid-sag in axia
(•) >= ( ) <
1.5 * variation between 2GTs
OR
Angular error of Mid-sag in coro
(•) >= ( ) <
1.5 * variation between 2GTs

Identify

Compute | Report

XIP Applications** designed as **Scene Graphs
Can replace components with your own in visual editor

*Statistics components written in **R***



AVT – Where are we ?

- **Initial RFP for Phase I Gap Analysis of requirements versus existing tools**
  - 2007/04 – drafted
  - 2007/12 – completed
- **Phase 2 Delivery of IA, AD and MVT components and framework**
  - 2008/07 – awarded
  - In progress
  - 2009/06 - delivery

AVT – What it means to you now

- **Success of all caBIG deliverables is predicated on wide spread adoption**
- **AVT is based on existing infrastructure**
  - XIP, AIM and CDE
  - NCIA
  - caGRID tools and services
  - R statistics
- **Evaluate and adopt these for**
  - communication and persistence
  - visualization and annotation
  - analysis
- **Then your project or algorithm will “plug in” to AVT !**