An Overview of LLNL’s newly developed CT Software package, Livermore Tomography Tools (LTT)

CASIS
May 13th

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Outline

• Introduction

• Motivation for developing the next-generation CT processing Software

• Livermore Tomography Tools (LTT), LLNL’s next-generation CT processing package Project Plan

• LTT design requirements and progress

• LTT Verification

• Summary
CT is widely used at LLNL for Non-destructive evaluation

**Global Security**

Al\Ni grain distribution & voids in intermetallic pellets. (Courtesy J. Sain)

**NIF**

Attempts to image aerogel to template DT ice layer in NIF target (Courtesy T. Willey)

**WCI**

Microstructure of High Explosives before & after temperature cycling (Courtesy T. Willey)

**WCI**

Additive Manufacturing Part (Courtesy C. Divin)
IMGREC is LLNL’s trusted CT Processing Code

- In use over 20 years
- Compatible with LLNL / NNSA scanners
- Algorithms to process varied data
- Peer-reviewed /published Algorithms
- Quantitatively accurate and resulting in physical units

But no longer meets emerging user requirements

Portability
Not released for MacOS and Linux

Extensibility
Not conducive to modern algorithms\hardware like GPUs

Maintainability
Limited documentation with a one developer team
LLNL requires a next-generation CT processing package

Commercial software packages were considered but it was determined that they do not meet LLNL/NNSA needs

- Incompatible with LLNL/NNSA scanners
- Use proprietary algorithms that are not documented in detail
- Are not quantitatively accurate and in arbitrary units

LLNL is investing an in-house CT software package, Livermore Tomography Tools (LTT)
LTT, LLNL’s Next-Generation CT processing Code Project Plan

Systems Engineering approach to development of LTT

• Requirements (FY13)

• Design\development (FY14-FY15)
  • Phase 1: command-line tool for basic pre-processing and analytical reconstruction
  • Phase 2: advanced algorithms and GUI development

• Verification

LTT v0.87 was released in FY14
LTT, LLNL’s Next-Generation CT processing Code

Project Plan

Systems Engineering approach to development of LTT

- Requirements (FY13)
- Design\development (FY14-FY15)
  - Phase 1: command-line tool for basic pre-processing and analytical reconstruction
  - Phase 2: advanced algorithms and GUI development
- Verification

LTT v0.87 was released in FY14
Livermore Tomography Tools (LTT) is LLNL’s Next-Generation Computed Tomography processing Code

**LTT Design Requirements**

- *Backwards compatibility with IMGREC*
  - Ability to read\write sct parameter file
  - Ability to read\write sdt\spr data files
Livermore Tomography Tools (LTT) is LLNL’s Next-Generation Computed Tomography processing Code

LTT Design Requirements

- **Backwards compatibility with IMGREC**

- **Portability across multiple platforms**
  LTT has been released for Windows and MacOS
  Future LTT releases will include support on Linux
Livermore Tomography Tools (LTT) is LLNL’s Next-Generation Computed Tomography processing Code

**LTT Design Requirements**

- *Backwards compatibility with IMGREC*
- *Portability across multiple platforms*
- *Leveraging modern hardware for Speed*
Leveraging modern hardware for Speed

Parallel computing is accomplished while maintaining portability

- Current LTT release utilize Multi – core processor hardware using OpenMP
  Upwards of a factor of 5 speed improvement over IMGRECV17

- Future LTT releases utilize GPUs using OpenCL
  Expected improved reconstruction time by a factor of 100 over IMGRECV17
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*LTT Design Requirements*

- Backwards compatibility with IMGREC
- Portability across multiple platforms
- Leveraging modern hardware for Speed
- Use software engineering best practices
LTT uses software engineering best practices

• Multiple developers for peer review and redundancy

• **Source Code is in Revision Control (Git)**
  Enables code development by multiple developers
  Code is backed up
  Releases are tagged

• **Issues are logged \ tracked using a bug tracker (JIRA)**
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LTT Design Requirements

- Backwards compatibility with IMGREC
- Portability across multiple platforms
- Leveraging modern hardware for Speed
- Use software engineering best practices
- Documentation
LTT Documentation

- CT Standards
  Description of scanner geometry\data processing

- LTT User’s Guide
  Description of the commands\use procedures.

- LTT Algorithms
  Description of implemented algorithms.

- LTT Software Design
  Description of software architecture

- LTT Verification
  Verification tests and results
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*LTT Design Requirements*

- Backwards compatibility with IMGREC
- Portability across multiple platforms
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- Use software engineering best practices
- Documentation

- Extendibility to modern algorithms
Extensibility to modern algorithms

Well-defined and documented algorithm interface

Easy addition of new algorithms
Extensibility to modern algorithms

Well-defined and documented algorithm interface

Easy addition of new algorithms
Extensibility to modern algorithms

Well-defined and documented algorithm interface

Easy addition of new algorithms

![Diagram showing LTT Algorithm List with interfaces for adding new algorithms]
Extensibility to modern algorithms

Well-defined and documented algorithm interface

Easy addition of new algorithms

Configurable processing pipeline
Extensibility to modern algorithms

Well-defined and documented algorithm interface

Easy addition of new algorithms

Configurable processing pipeline

Common Memory Management Infrastructure

- Chunking
- In-place processing
- In – RAM processing
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**LTT Design Requirements**

- Backwards compatibility with IMGREC
- Portability across multiple platforms
- Leveraging modern hardware for Speed
- Use software engineering best practices
- Documentation
- Extendibility to modern algorithms
- Command – line scripting and GUI
Command line interface : LTT script

• Is a simple text file
• Allows custom processing pipeline
• Used for batch processing

LTT GUI development is underway

Qt GUI is portable to Windows, MacOS and Linux
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LTT Verification

Reconstruction algorithm Verification using simulated data (HADES)

- A simple 2-spheroid (Aluminum \ Graphite) scene was simulated for
  - Various scanner geometries
  - Reconstruction volume definitions
  - Reconstruction algorithm parameters
- Suite of Metrics calculated versus ground truth

End–to–end Verification using Experimental Data

Melamine Wax part, ALS LBL (Parallel beam)

Reference Materials, Micro CT Test bed (Fan Beam)

Water sample, Micro CT Test bed (cone beam)
Summary

- LTT v0.87 was released
  - used at LLNL by NDE engineers at HEAF
  - Used externally at Tyndall Air force base

- Excellent progress towards upcoming LTT releases.

- On – track to reach proposed goals by the end of FY15.