X I P

Rapid and Extensible Software Development for Medical Imaging

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Challenges:
Product Integration and Interoperability

Integrating the results of academic & clinical collaborations, software platforms of different companies and third-party applications into a unified architecture is a major challenge.

150+ students
Sponsored by SCR each year

Acquisitions of medical imaging companies

Integration of 3rd party applications

QSR-Compliant PRODUCTS
Megatrend: Imaging Biomarkers in Drug Discovery
Molecular Imaging Software Development Pipeline

Probe / Target / CA Discovery, Animal Testing
Clinical Trials
Clinical Feasibility and Acceptance
Clinical Operations

- 10’s to 100’s of new disease-specific molecular imaging applications in next 10 years
- Radiologists Need:
  - Agent-customized imaging
  - More efficient development for clinical research
- Hospitals Need:
  - Agent-optimized imaging across all workstation platforms

A new model for imaging software development is needed to efficiently bring molecular agents to the clinic
Accelerating Time To Market

Rapid Transfer from Prototype to Product

Product Workstation
  Siemens Syngo, GE Advantage, ...

Research Workstation
  • XIP Host, AVT, 3D Slicer, ...

Development Platform
  • XIP Builder

Components
  • Java Applets, .NET/ActiveX, Qt WebKit, ...

Toolkits
  • ITK, VTK, DCMTK, Open Inventor, ...

Libraries
  • OpenGL, GLSL, CUDA, ...
Rapid Prototyping IDE provides a graphical editor to create visualization graphs and processing pipelines.

Standalone application easily deployable to clinical collaborators is used to refine workflow and algorithms based on their feedback.

Standardized middleware and components to ease the integration of prototyping results into product platform for clinical applications.
Feedback from Pharma Plug-in Concept

- Why re-implement the same image analysis software for a particular agent on each vendor’s workstation?
  - An interoperable plug-in environment can facilitate collaboration between imaging vendors and Pharma companies, enabling new business models.

Market the combination of a molecular imaging agent with its disease and organ specific image acquisition & analysis.

Commercial workstations are extended to execute drug-specific plug-ins.

...and many other imaging vendors.
DICOM Working Group 23

Created in December 2004, with support of Siemens Corporate Research

Chaired by Lawrence Tarbox (WUSTL)

Joined by Siemens, GE, Philips, Kodak, Agfa, Barco, FujiFilm, Oracle, and many more

Providing an “Application Hosting” reference implementation in 2009 (Supp. 118)

DICOM Supplement 118 is open for public comment as of Jan. 2009
ftp://medical.nema.org/medical/dicom/supps/sup118_pc.pdf
caBIG community is composed of 900 developers from 50 NCI-designated Cancer Centers and a multitude of organizations working on over 70 projects.

- NCI needed an open-architecture development environment for rapid prototyping & collaboration.
- NCI funded the creation of XIP in order to have an extensible platform for caBIG’s Imaging Workspace.

**eXtensible Imaging Platform (XIP)**
- Includes a reference implementation of WG23 emerging standard.
- Collaboration with Mallinckrodt Institute of Radiology (WUSTL).
- First release of XIP was available to caBIG community Spring 2007.
Interactive Design of Open Inventor Scene Graphs and pipelines
Instead of implementing yet another library design, XIP extends Open Inventor ® (free, LGPL) with new engines, nodes, and manipulators for Medical Imaging:

- **Engines** enable the creation of **processing pipelines** → well known concept in Computer Vision
- **Nodes** support the concept of **scene graphs**, which are hierarchical structures of objects describing what needs to be visualized in 2D/3D → well known concept in Computer Graphics
- **Manipulators** handle input devices, measurements and coordinate transforms in response to user interaction via a simple event model
- **Field Converters** automatically handle data conversion between different field connection types → facilitates interoperability between wrapped libraries
- **Serialization** is built-in via Open Inventor’s VRML standard → facilitates exchange of functionality

Leveraging excellent Sgi’s documentation for a short learning curve (Inventor Mentor/ToolMaker)
XIP Builder Visual Programming Tool

Highlights

- Makes many different open source libraries interoperable (Open Inventor, ITK, VTK, DCMTK, GLSL, CUDA, AIM,...)
- Design can be rapidly prototyped, tested and saved to a file which can be loaded in application GUI written in C++, Java or HTML
- Ability to group sub-graphs into high level reusable packages
- Tabbed navigation facilitates navigation through large projects
- Ability to preview processing results at any stage of the graph/pipeline
- Watch window for debugging purposes
- Integrated Performance Profiling feature
- Built-in batch mode processing for automated testing/validation
XIP Host Reference Implementation

- Provides the infrastructure in which XIP or DICOM WG-23 Applications run
  - Authenticates user
  - Manages installation, launching, and termination of XIP Applications
  - Provides data and services to XIP Applications
  - Accepts status information and results back from XIP Applications
  - Deals with auditing and controls access to services and data

- Isolates the XIP application from the nature of databases, archives, networks, and possibly image data formats
  - Manages caGRID interactions and security
  - Manages access to DICOM networks, objects, and services
  - Maps images and associated meta-data between their native form and a common form useable by the XIP application
  - IHE General Purpose Worklist support
ITK Support

- Scripts to automatically wrap entire library (1000’s of objects)
- 261 wrapped objects are fully tested
- 125 examples matching the IKT User’s Guide
Scripts to automatically wrap entire library (1000’s of objects)
- 308 objects undergoing testing
- Various examples available (under development)
DICOM Support

- High-level DICOM loader objects based on DCMTK
- Modular DICOM Sorting objects
- Objects for 2D on-demand-paging as well as 3D volume construction
- Flexible display of DICOM elements as overlay text information
GPU Image Processing

- Support for GLSL programs (C-like language)
- All underlying OpenGL 2.0 setup is taken care of
- Easy way for researchers to implement hardware-accelerated algorithms
Leverages the processing power of modern GPU graphics cards (within the constraints of the GPU card’s memory, and using only standard algorithms known in the art)

Fully programmable using the GLSL language

Great flexibility for researchers to implement new 3D visualization ideas

Supports multiple volumes fused in the same scene

Synchronized 3D navigation of Oblique MPR planes
A collection of 2D/3D shapes for a variety of image markup applications (lines, polygons, splines...)

- RECIST, WHO, area and volume measurements
- Graph plotting and charting
- Support for DICOM Presentation States
Remote Client/Server Visualization

- Enables collaborative visualization over LANs, Intranets and/or the Internet
- Volume rendering and MPR fully supported
- Socket-based, it only needs the IP address of the XIP server process
- Remote loading on server is triggered by the client
Upcoming Feature:
Multi-Resolution Client/server approach

- Virtual Autopsy Workstation funded by Swedish government
- Uses full-body 0.3 mm dual-energy scans
- Linkoping Univ CMIV + Siemens + Sectra

Large data is on the back-end
Application logic and LOD selection is on the front-end
Recent New Features:
Integrated Performance Profiler

- Visual representation of performance in order to easily identify bottleneck and optimize execution
Recent New Features:
Automatic HTML Document Generation

- Generates design documentation
- Can store/print requirement keys, class descriptions, connection diagrams

```
markerType     DIAMOND
markerColor    0.88 0
lineColor      0.88 0

#154 - DrawStyle
Field          Value
lineWidth      = 3 px

#155 - SxXlPlot2Curve "FittedCurve"
Field          Value
label          "Fitted Curve"
data           = rec. @ #112
markerColor    0.88 0
lineColor      0.88 0

#156 - Separator

The nodes #127 and #122 are children of this group.

#157 - SxXlImageText
Field          Value
position       TB, UPPER, CENTER
text           = sxlDrawString @ #118

#158 - SxXlGetFittedCurveInfo
Field          Value
position       = coordinate @ #112
radius         = itemVal @ #112
t            = rec. @ #132
tp            = rec. @ #132
c            = itemVal @ #122

#159 - SxXlDisplayImageText
PLOT_DynamicPixelCurve

PLOT_ParametricPixelCurve

This package is responsible for displaying the panel curve and corresponding fitted curve of a time series, given a coordinate. The coordinate can be either extracted via the pan/zoom tool (interactive mode, uses a 3x3 kernel) or by picking (bigger kernel size allows for smoothing).

The point field holds the coordinate obtained via picking.

The point field holds the coordinate obtained via pixel lens.
```
Recent New Features:
CUDA-based High-Performance Computing

- Introduced at MICCAI HPC Workshop 2008 (V. Giden, P. Ljung, G. Paladini, T. Moeller)
- Currently adding: Global Memory Management for both CUDA and Texture memory; 3D texture processing; collection of CUDA-accelerated algorithms (distance transf., PDE solver, non-linear diffusion filtering, etc.)

- nVidia Tesla C1060 – 0.9 TERAFLOPS
- nVidia Tesla S1070 – 4 TERAFLOPS

(a) Output data from the pipeline engine is used to create OpenGL textures.

(b) OpenGL textures are used to create CUDA data which is processed by kernels in the pipeline engine.
Recent New Features:

View and Control Scene Graph with HTML/JavaScript
Recent New Features:
Support for Qt UI Designer, Qt JavaScript, Python Script
Recent New Features:
Example of XIP volume rendering inside 3D Slicer
XIP Automatic Test Cases

- XIP Builder tool can run and execute programs in Batch Mode
- Command Mode syntax makes it possible to vary parameter values in order to create tests that validate XIP libraries
- 100’s of tests already available
XIP Wiki Site for Imaging Framework

- Wiki is available at [https://collab01a.scr.siemens.com/xipwiki/index.php/Main_Page](https://collab01a.scr.siemens.com/xipwiki/index.php/Main_Page)
- Main web site for documentation, tutorials, reference help
- Clicking on any objects in XIP Builder and pressing F1 pop-us an online help page for such object
- Wiki allows caBIG developers to document their own objects in a central repository
XIP GForge Site

- GForge developer’s site can be accessed via the XIP Wiki
- Main web site for daily source code development and latest installation packages
- Stable, frozen releases are mirrored into caBIG’s GForge site
- Provides SVN-based repository, forum, bug tracking tool, Cmake automated builds, Dashboard

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<td>Added XIP core. Complated ITK port.</td>
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<td>Added more classes to core that are needed by overlays.</td>
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<td>StiplesCursor.cpp</td>
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<td>gein</td>
<td>Added an image viewer, a Raw image loader, a viewport group and some utility.</td>
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Boost in Productivity
More than 30 clinical prototypes/year based on XIP Builder
Determined Value of Open XIP Platform

Some ongoing projects based on Open XIP – Government & Academia

- caBIG Open Source imaging libraries and XIP Builder Tool
- caBIG AVT Project (Algorithm Validation Toolkit)
- DoD TATRC/ACR’s Interoperability in Medical Imaging
- DARPA deep-bleeder acoustic coagulation
- Beth Israel Intraoperative Fluorescent Imaging
- NTROI Optical Imaging for Drug Therapy Monitoring
- caBIG AIM Project (Annotation Imaging Markup based on XIP) - Northwestern Univ.
- UPENN prostate cancer multi-resolution histopathology fused with MR
XIP for the Dept of Defense:
Congressional Project led by ACR

- Soldiers frequently suffer from types of injuries that are rare for civilians, e.g., Traumatic Brain Injury (TBI) from Improvised Explosive Devices (IEDs)
- DOD Healthcare needs the ability to rapidly field vendor interoperable imaging solutions for such unique problems. ACR/SCR are working with the Army (TATRC) and the Navy (NNMC) to demonstrate that XIP & WG23 can meet these needs
- This project will leverage XIP and Qt’s cross-platform compatibility and will deliver a TBI application running on Mac OS X
- MR anatomy, connectivity map, diffusion tracts, fMRI activation, segmented surfaces
XIP and caBIG Algorithm Validation Tools (AVT)

Image Analysis & Annotation
- Measure/annotate tumors with XIP

Assessment Database
- Captures Annotations & Provenance Data

Measurement Validation
- Computes measurement statistics and correlations between metrics and outcomes

- **XIP is the foundation of other caBIG tools, including AVT, which will be used to validate tumor change quantification algorithms for clinical trials**
Clinical Diagnostics
Data Analysis:
• Diagnosis of patient for appropriate treatment

Preclinical Development
Data Analysis:
• Identification of disease biomarkers, development of drug candidates

Validation
Data Analysis:
• Determine if algorithms are computing accurate measurements

Clinical Trials
Data Analysis:
• Measure progression of disease to determine if a drug works or not

Modular Plug-in Framework
- Visualization
- Registration
- Segmentation
- Measurements
- Data Management
- ...

New advanced algorithms are validated for the purpose of being used in a regulated Medical Device (FDA QSR Compliance)

Common XIP platform between preclinical and clinical trials allow rapid translation of animal results to human applications

Huge amounts of data collected during trials is used to advance biomarker detection algorithms (knowledge based image analysis)
Thank you for your attention!

For more information, please contact:

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