Design of High Performance Imaging Analysis Systems and Software

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NSF Year 10 Site Visit
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CenSSIS Image and Data Information Management – “The R3 Thrust”

- Addressing key research barriers in image reconstruction and understanding, software engineering and data management
- Exploiting hardware/software acceleration/parallelization to enable new discovery in SSI applications
- Producing an image/data repository and software-engineered Subsurface Sensing and Imaging Toolsets
Major Outcomes From 10 Years of NSF Funding

- Leadership in biomedical high performance computing
  - Participation in parallel image reconstruction algorithm development
    - Breast Tomosynthesis
    - Cardiac CT Reconstruction
    - 4D-CT for Radiotherapy
  - GPU Computing – from days to seconds!
- Image database management technology
  - Infrastructure for the PROTECT project
- Toolbox develop leading to new business ventures
  - Dual-Align LLC – photomosaicking and image montaging
  - HySpeed Computing LLC – hyperspectral image analysis, remote sensing, environmental monitoring
CenSSIS R3 Researchers

Faculty/Staff
- Dana Brooks – NU
- George Chen – MGH
- Charles Dimarzio - NU
- Synho Do – MGH
- James Goodman - UPRM
- James Hale – Spelman
- Shawn Hunt – UPRM
- Luis Jiménez - UPRM
- David Kaeli - NU
- Miriam Leeser – NU
- Waleed Meleis – NU
- Richard Moore - MGH
- Homer Pien - MGH
- Wilson Rivera - UPRM
- Samuel Rosario – UPRM
- Nayda Santiago – UPRM
- Greg Sharp - MGH
- Charles Stewart – RPI
- Miguel Velez – UPRM
- Alfred Watkins - Spelman

Graduate students
- Malak Alshawakeh - NU
- Emmanuel Arzuaga - NU
- Fatemeh Azmandian – NU
- Sherman Braganza - NU
- Maria Constanza-Torres – UPRM
- Burak Erem – NU
- Carolina Gerardino – UPRM
- Byunghyun Jang – NU
- Avi Kelman – RPI
- Jorge Manrique - UPRM
- Perhaad Mistry - NU
- Rafal Norton – NU
- Diego Rivera - NU
- Dana Schaa – NU
- Matthew Sellitto - NU
- Blas Trigueros – UPRM
- Xiaojun Wang - NU
- Gehua Yang – RPI
- Jaime Yeckle – UPRM
- Juemin Zhang - NU
CenSSIS R3 Researchers

**Undergraduate Students**
- Christine Cortes - UPRM
- Suzette Gomez – UPRM
- Yajaira Gonzalez - UPRM
- Stephen Hobson – NU
- Chawandia Mack – Spelman
- Gabriel Martinez – UPRM
- Jade Martin - Spelman
- Martin Ramirez – UPRM
- Ruben Rios - UPRM
- Christian Sanchez – UPRM
- Joralis Sanchez – UPRM
- Justin White - NU

**Undergraduate Students**
- Carolyn Andrews – NU
- Jennifer Bennett - Spelman
- Angel Clark – Spelman
- Kelli Crosby – NU
- Nicholas Dedual – Northeastern
- Danielle Edwards – Spelman
- Chanelle Green – Spelman
- Simone Hunter – Spelman
- Buffy Johnson – Spelman
- Jacinta Mba – Spelman
- Kyle Nadeau – NU
- Jason Selwyn - NU
- Adam Williams – Trinity College
Impact on the International High Performance Computing Community

- GPGPU-1 Workshop held with the Year 8 RICC – 250 attendees!
  - Special issue of the Journal of Parallel and Distributed Processing in 2008
- GPGPU-2 Workshop held with ACM ASPLOS in 2009 – 50+ attendees
  - Proceedings published by ACM International Conference Series in 2009
- GPGPU-3 Workshop held with ACM ASPLOS in 2010 – 70+ attendees
  - Proceedings published by ACM International Conference Series in 2009
- NU-AMD GPU Workshop – June 10, 2010 @ Northeastern University
- Special session at IEEE International Symposium on Biomedical Imaging – “Biomedical Computing on Many Cores” – June 2009
Developing a suite of Biomedical Image Reconstruction Libraries – CUDA/OpenCL

- Target applications:
  - Deformable registration - radiation oncology
  - 3-D Iterative reconstruction – cardiovascular imaging
  - Maximum likelihood estimation – Digital Breast Tomosynthesis
  - Motion compensation in PET/CT images - cardiovascular imaging
  - Hyperspectral imaging – skin cancer screening
  - Image segmentation – brain imaging

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Legacy of R3 Software Projects

- 3 completed CenSSIS toolboxes
  - http://www.censsis.neu.edu/
  - More than 400 downloads annually
  - Continued support for The Coastal Image Analysis Toolbox (HyCIAT)
    - A toolset for the study the water optical properties, bathymetry and fractional abundances using hyperspectral image analysis

- Apply CenSSIS Database to address new problems
  - NIEHS PRoTECT proposal
    - Environmental, biological and demographic data in a single repository
    - Providing data mining and GIS tools for enhanced data management/analysis
Focus on sustainability - Won sustaining proposals, developed new university and industrial ties, submitted new proposals

- NSF STTR, NSF MRI, AMD, NVIDIA, NIEHS, Simquest, UIUC, Univ. of Delaware, Georgia Tech, NIH, NIST, NSF IGERT and DARPA
- NSF ERC Innovation Grant – Biomedical Imaging Acceleration Testbed
- Analogic/BK Ultrasound Project
- HySpeed Computing and Simquest SBIRs
- Both NVIDIA and AMD are focusing on CenSSIS partners for a “Center of Excellence” or “Research Center” site
  - Foci are Biomedical Image Analysis and Compiler Optimizations
R3 Contributions over 10 years

- **Acceleration of Image Reconstruction**
  - Application of FPGA, Grid Computing and GPU devices to a wide range of imaging applications and visualization
    - GPU research funded through 2013
  - A suite of GPU parallelization tools and techniques

- **CenSSIS Toolboxes**
  - Heavy use of 3 existing toolboxes by government, industry and academia (and CenSSIS S-level projects)
  - A repository of robust tools ripe for commercialization – e.g., DualAlign and HySpeed Computing

- **CenSSIS Database**
  - Provides a basis for future database projects

- **A new generation of engineering graduates trained in cutting-edge SSI technologies!**