Computational Tools for Radiation Modeling and Education of Professionals in Cancer Radiation Treatment

Alan Sill and Ravi Vadapalli
*High Performance Computing Center, Texas Tech University*

Lawrence Pinsky
*Dept. of Physics, University of Houston*
Introduction and Background
Radiation therapy for cancer treatment and related options have undergone rapid technical development.

Current methods have outstripped our ability to teach doctors and technicians more than the basics of the use of these tools!
Multiple Techniques

- Vendors sell dose estimation systems with equipment, but often fail to educate doctors about alternative methods.
- Each system is proprietary and unique.
- Hard for any doctor or technician to keep track of all of the methods, and know how to choose the best system for each patient.
The Need
Cancer Treatment Education

- We need to develop and implement a modern, comprehensive curriculum for technicians, radiation oncologists and medical students to bring them up to date with the latest methods.

- Make a range of tools available to students in a way that makes them easy to use.

- Solve the problems of computation and access to make these work in the classroom.
Further Goals

- While the research community in various forms of radiation therapy is highly developed (gamma/X-ray, electron, proton, neutron, seed implantation of sources, various forms of intensity-modulated and location-modulated delivery, etc.), few tools exist to allow simultaneous modeling and evaluation of projected outcomes by students.

- To be effective in education, classroom standards for physics and other science preparation as well as the above tools need to be developed.
Problems to Solve

○ Need committed educational staff and faculty at each of the institutions.

○ Must have access to experts!

○ Need standards against which to evaluate the characteristics of such a program.

○ Must understand “value added” of such a program.

○ Must produce a comprehensive change in students.

○ Must make tools much easier to use.
Participants
Collaborations for R&D Active in Texas

- Texas Tech University, MD Anderson and University of Houston.
- NASA/Houston + FLUKA collaboration developing extensive tools.
- MD Anderson Cancer Center, Rice, and an extended collaboration including Washington U., UW and LSU are also active.
Collaborations Elsewhere

- Particle Therapy Co-Operative Group
  http://www.ptcog.com

- Panel on Gamma and Electron Irradiation
  http://www.irradiationpanel.org/

- Monte Carlo Neutron, Electron and Gamma Group (MCNEG) (UK)
  http://www.mcneg.org.uk/

- FLUKA Monte Carlo collaboration
  http://www.fluka.org

- GEANT Monte Carlo simulation toolkit
High Performance Computing
Radiation Therapy Treatment Planning

Using Raw CT-Scans and Monte Carlo Programs From Particle Physics to Simulate Radiation Therapy Doses

V. Andersen¹, F. Ballarini²,³, G. Battistoni³, F. Cerutti³,⁴, A. Empl¹, A. Fasso⁵,⁶, A. Ferrari³,⁵, M.V. Garzelli¹³,⁴, A. Ottolenghi²,³, H. Paretzke⁷, K. Parodi¹¹,¹², L. Pinsky¹, J. Ranft⁵,⁸, P. Sala⁹, T. Wilson¹⁰ and M. Zankl⁷

¹University of Houston, Houston, Texas, USA; ²University of Pavia, Italy; ³INFN, Italy; ⁴University of Milan, Italy; ⁵CERN, Geneva, Switzerland; ⁶SLAC, Stanford, California, USA; ⁷GSF, Neuherberg, Germany; ⁸University of Leipzig, Germany; ⁹ETH, Zurich, Switzerland; and ¹⁰NASA-JSC, Houston, Texas, USA, ¹¹GSI, Darmstadt (& Heidelberg), Germany, ¹²MGH, Boston, MA
Application of Grid Computing to Radiation Cancer Therapy

Wayne Newhauser,
Yuanshui Zheng, Jonas Fontenot, Phil Taddei,
Dragan Mirkovic, Uwe Titt, and Radhe Mohan

TIGRE Developers Meeting
Rice University
October 12-13, 2006
Research Team
Late Effects of Radiotherapy for CNS Cancers

- MDA: Kornguth, Yang, Martel, Taddei, Giebeler, Mirkovic, R Zhang, Harvey, Titt, Broaded, Krishnan, J Chang, Zhu, et al.
- Rice: Yepes, Randeniya, et al.
- LSU: Fontenot
- UW: DeLuca, Perez
- Wash U: Zheng
- And others like you

From MD Anderson research talk by W.D. Newhauser - used by permission
Tools Available
Monte Carlo Methods

- Represent stochastic processes probabilistically using random number generators.
- Simulate motion of the particles through matter using known microscopic physics processes.
- Requires accurate knowledge of physical geometry and composition of tumor and its neighborhood.
- “Score” energy deposited and calculate dose endpoints statistically for designated volumes within the geometry by running many incident trial particles.
- Popular codes include MCNPX, FLUKA, and GEANT4.
- Computationally intensive in both data and CPU.
Monte Carlo Simulation of Treatment

- Range-modulator wheel
- Scattering foil
- Range-shifting plates
- Range compensator
- Field-defining collimator

(Courtesy W.D. Newhauser)
New Capabilities for Treatment Planning With *Biological* Endpoints

Proton absorbed dose

Neutron absorbed dose

Newhauser et al, AIP Proc 2008
Interactive PET-guided dose quantification

Initial PET comparison

K. Parodi, Ph.D. Thesis,
TU Dresden 2004

Interactive CT modification and fast PET recalculation

Plan recalculation on modified CT

Planned dose on MODIFIED CT

PETcalc. ORIGINAL CT
PET calc. MODIFIED CT

PET meas.

MD Anderson MC & Proton Therapy
Pinsky - Sept. 21, 2007
In-beam PET for $^{12}$C therapy @ GSI

Extraction of ion range in-vivo
Validation of the physical beam model of treatment planning

1998

Since 1999

1. Precision measurements:
   Range of $^{12}$C-ions in tissue
   (D. Schardt et al. GSI)

2. Modification:
   $R = R(HU)$
   (E. Rietzel et al. GSI)

Courtesy Katia Parodi
Heidelberg Ion Therapy Center,
Heidelberg (via L. Pinsky)
Computing
Resources exist at the campus level at many of the institutions involved that can make access to computation needed to run these models much more practical than on the average PC or laptop.

Most of the campuses involved have one or more central clusters and/or campus grid computing networks.

In addition, common tools can be developed and created on a multiple-campus cooperative model.
THE TIGRE PROJECT:
AN EXAMPLE OF A STATE-WIDE GRID

Current effort is to develop into a HiPCAT-based OSG VO

TIGRE project funded by legislation that also enabled LEARN expansion; project completed late Dec. 2007.
Suragrid Grid Computing Project

Lowering the barriers for deploying and utilizing local, regional and national CI

- 30 participating institutions
- Shared accessible grid computing environment
- Access to group negotiated discounted HPC systems
- Enabling CI supported research & education
- On-Ramp to National CI projects

See: [www.sura.org/suragrid](http://www.sura.org/suragrid) for more information.
30 Virtual Organizations, hundreds of members, >10,000 cpus.
Total aggregate capability across all VOs ~80 TF
TeraGrid National Supercomputer Project

Computational Resources
(size approximate - not to scale)

SDSC
NCAR
TACC
UC/ANL
NCSA
ORNL
PU
IU
PSC
LONI/LSU
Tennessee

2007
(504TF)
2008
(~1PF)

Slide Courtesy Tommy Minyard, TACC
Conclusions on Computing

- Adequate resources exist to provide real-time access to computing on the scale that would be needed to support multiple students and research participants.

- Tools are increasingly oriented to and compatible with deployment on large-scale national and other regional and local grid/distributed computing resources.

- Virtual organizations exist that are interested in or customized to meeting this need.
Several of the institutions named in this talk are in the process of creating Medical or Biological Physics degree programs aimed at carrying out the goals mentioned here.

MD Anderson Cancer Center is actively collaborating with several of these on both R&D and educational goals.

Collaborations just forming to develop curriculum standards in this area. (Contact us for details.)
Opportunities exist to undertake curriculum development for a comprehensive program of education in modern radiation treatment and related modeling tools.

This will fill a need for better-educated radiation oncologists, MD practitioners and a new generation of cancer treatment specialists.

Can be integrated into the program of instruction for several institutions.

Progress being made on associated computing and curriculum standards.