Biomedical Science and Engineering at Oak Ridge National Laboratory

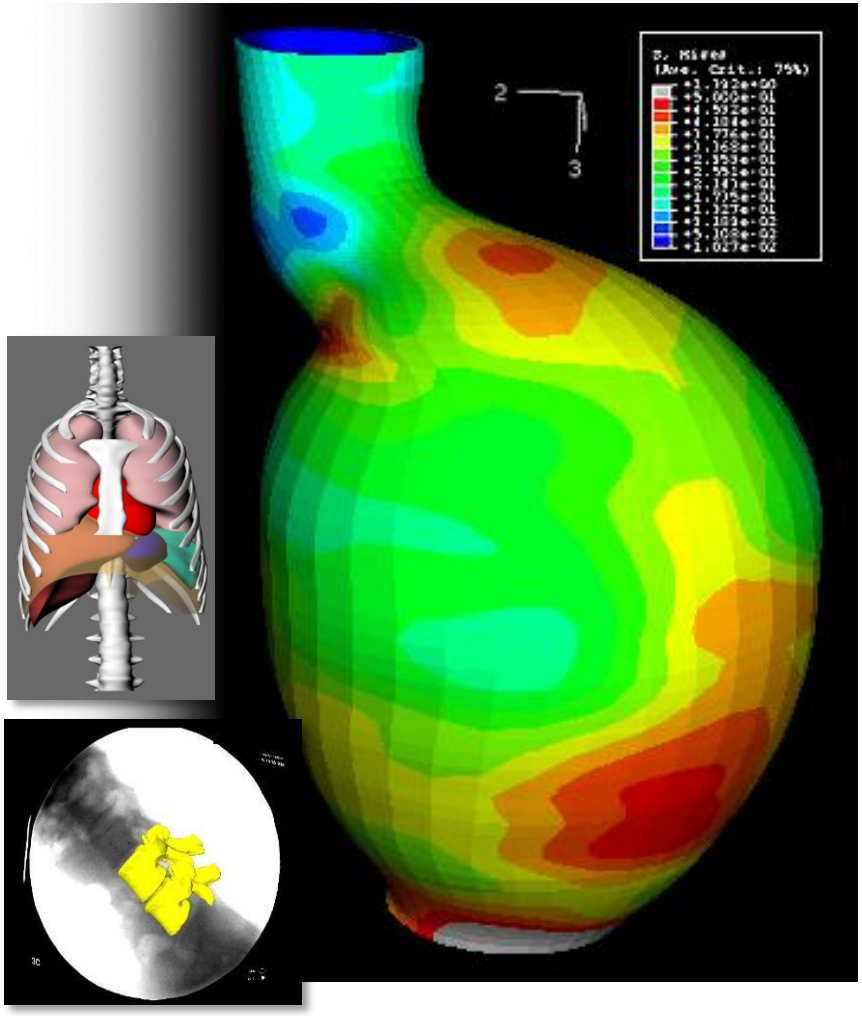
Presented by

Barbara Beckerman

Modeling and Simulation Group
Computational Sciences and Engineering

Biomedical engineering and biomedical informatics research at ORNL

- Biokinetic and biotransport modeling
- Three-dimensional organ and tissue modeling using CT or other imagery (pulmonary, arterial, musculoskeletal)
- Prediction of outcomes based on biomedical models
- Knowledge discovery and intelligent agents for data mining and analysis
- Integration of models at multiple temporal and spatial scales
- Computer environments (data repositories, search tools, visualization, etc.) in support of biomedical and medical applications
- Biomedical informatics and telemedicine

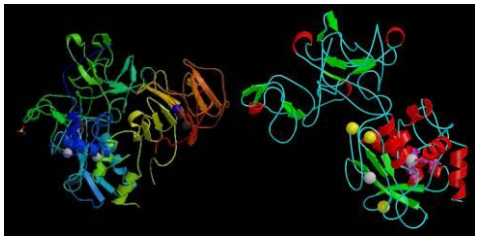


Predictive multiscale modeling

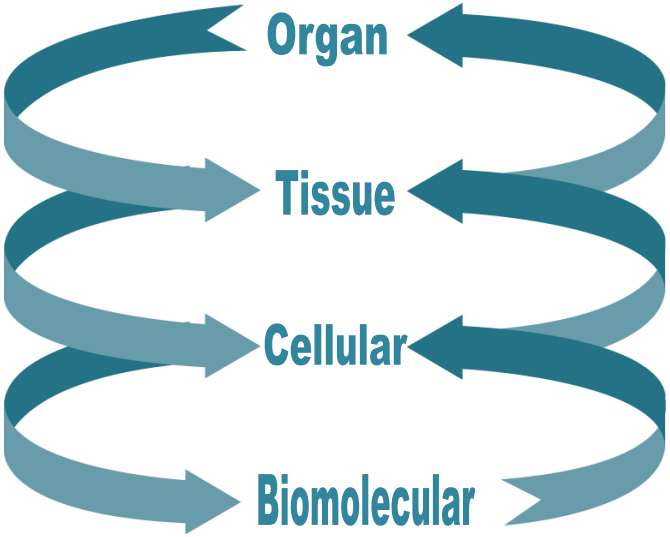
Goal: Predict migration of smooth muscle cells from media to intima due to inflammatory response after injury

Model for predicting vascular disease

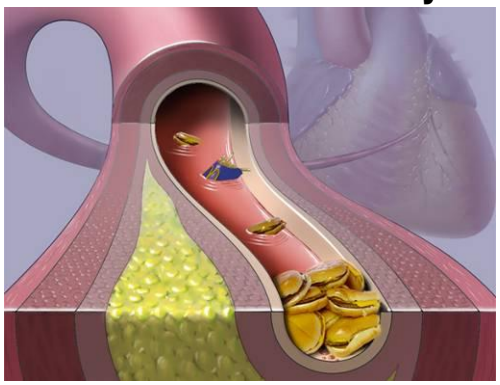
- Spatial modeling of cell migration
- Diffusive and kinetic modeling of biochemicals
- Result: A multiscale hybrid continuous-discrete predictive model for tissue pathology



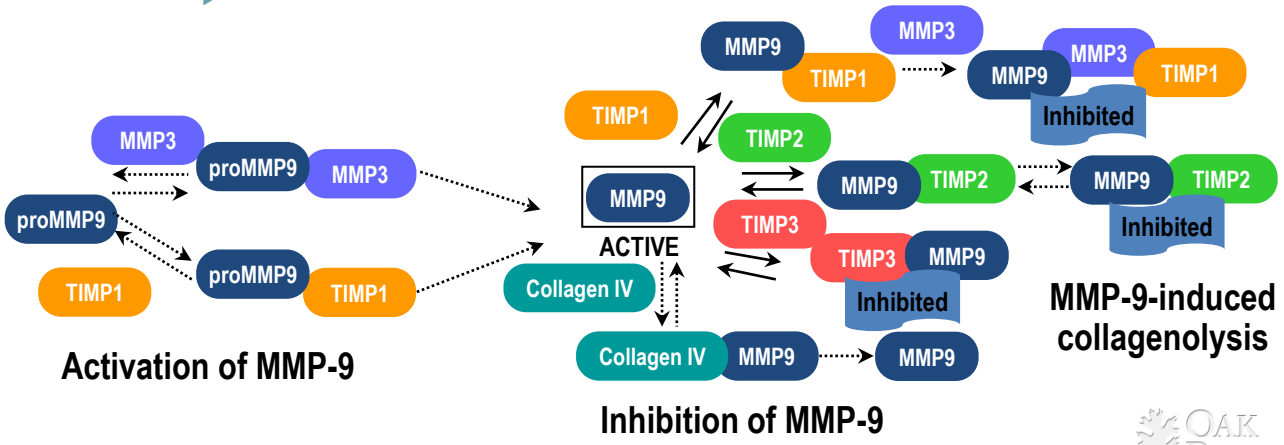
Matrix metalloproteinases (MMPs)



Atherosclerotic artery



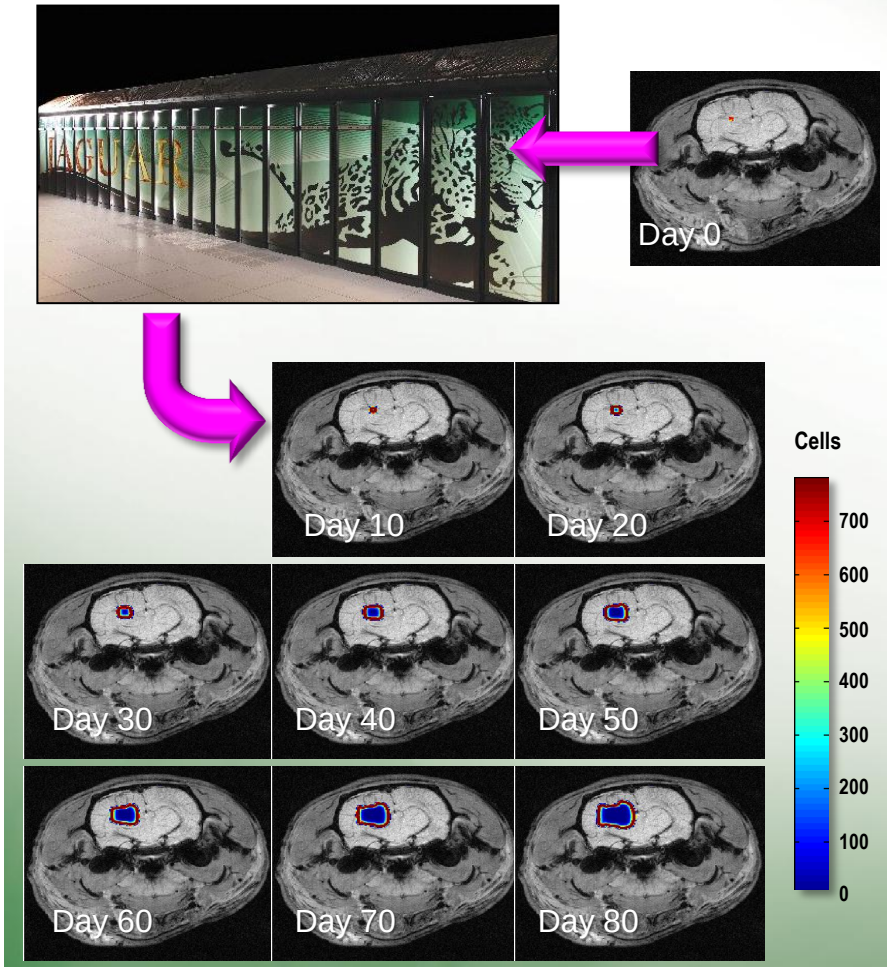
R. Conway 2005, zoologynews.blogfa.com/post-23.aspx



Qualitative system identification for tumor modeling

Modeling and Simulation Group

Computational Sciences & Engineering Division



Problem Statement:

ORNL is working with collaborators at the Vanderbilt University Institute of Imaging Science (VUIIS) to build and demonstrate a high performance, inductive reasoning engine for discovering models of tumor growth from features in time series images of mouse models of human breast cancer

Technical Approach:

Our approach integrates fuzzy inductive reasoning, genetic algorithms, and high performance computing to enable the construction of dynamic models *directly* from imaging characteristics that correlate with disease outcome

Benefit:

New methods and technology for the identification of clinically relevant, prognostic features that separate responding and nonresponding tumors early in the course of therapy, and a general and practical method for modeling biological processes directly from features in imaging data

Point of Contact:

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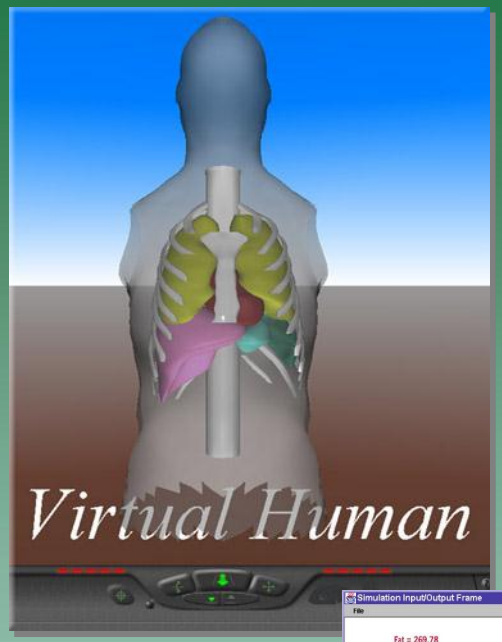
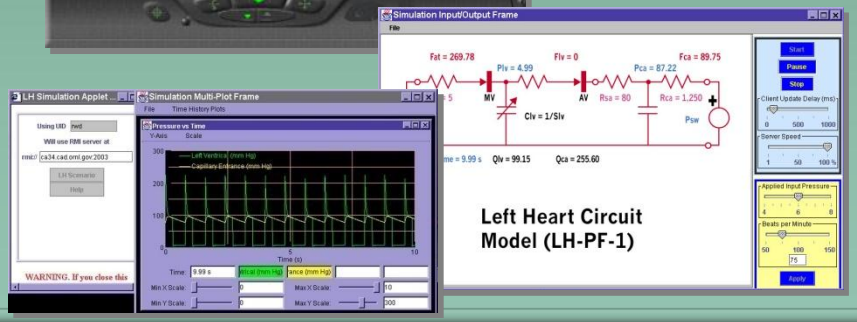
OAK RIDGE National Laboratory

Cardiovascular modeling environments

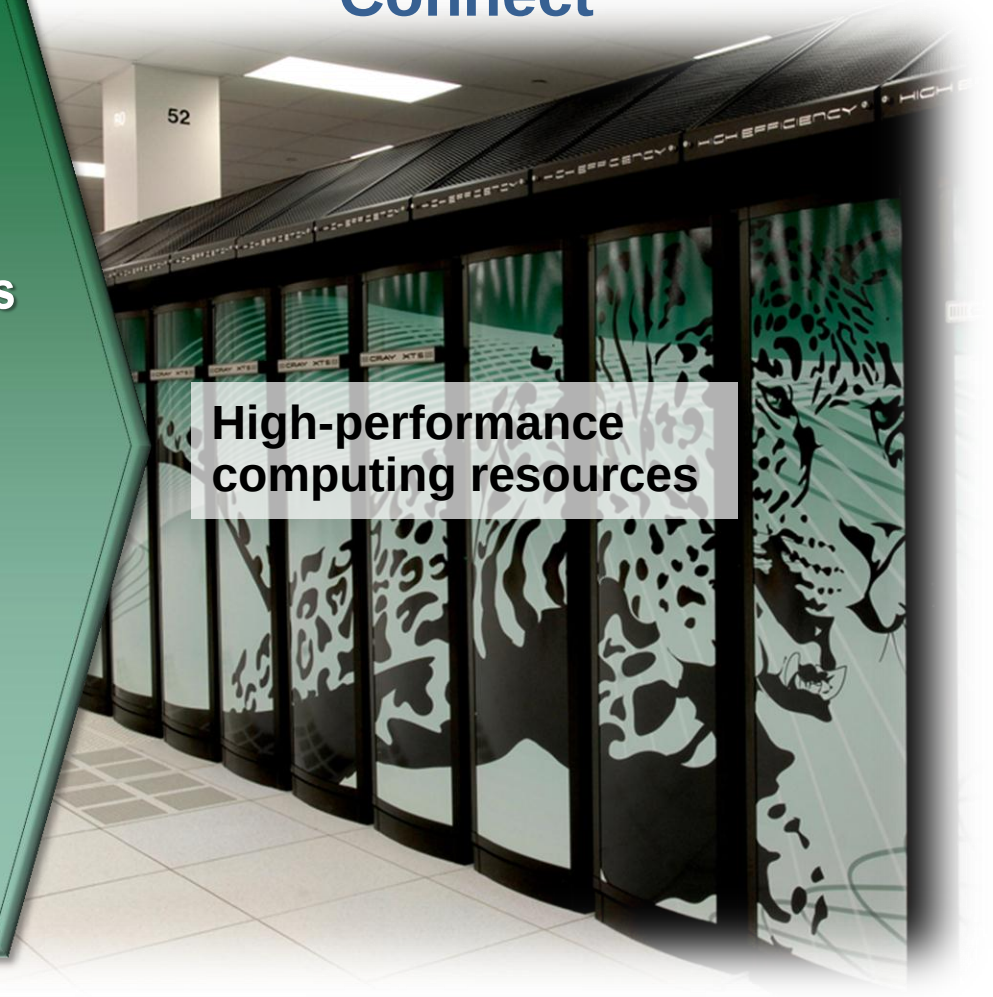
Integrate



- Models
- Computations
- Visualization
- Predictions



Connect



High-performance computing resources

Neuroscience research areas

http://www.brain-club.com/result.php?Keywords=acquired+brain+injury&host=www.brain-club.com&cat=1

TBI

Neuronal Development/ Migration

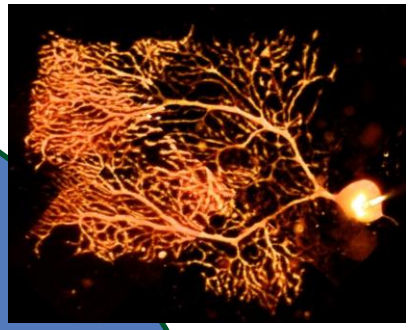


Image provided by Ryan Kerekes, ORNL

Nanostructured Materials

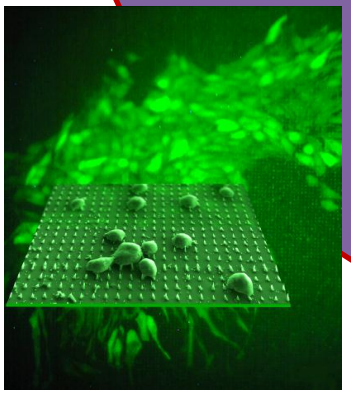
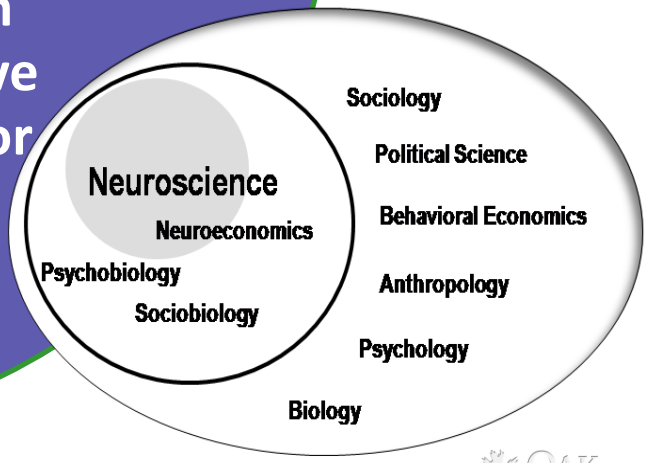
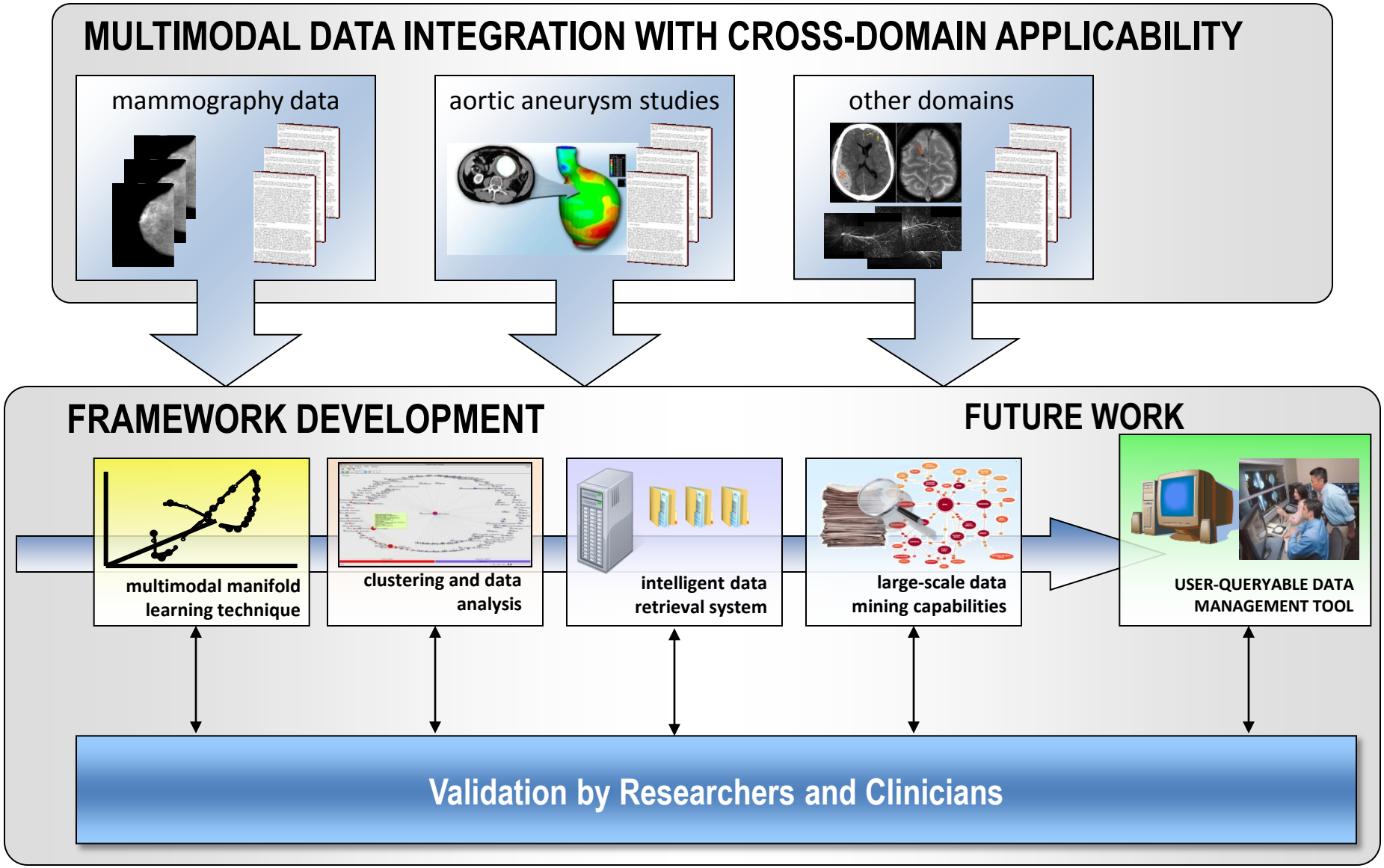


Image provided by Tim McKnight, ORNL

Human Cognitive Behavior



Multimodal data integration



DAMSEL: Data Analytics for Medicine Using SEmi-supervised Learning*

Objective:

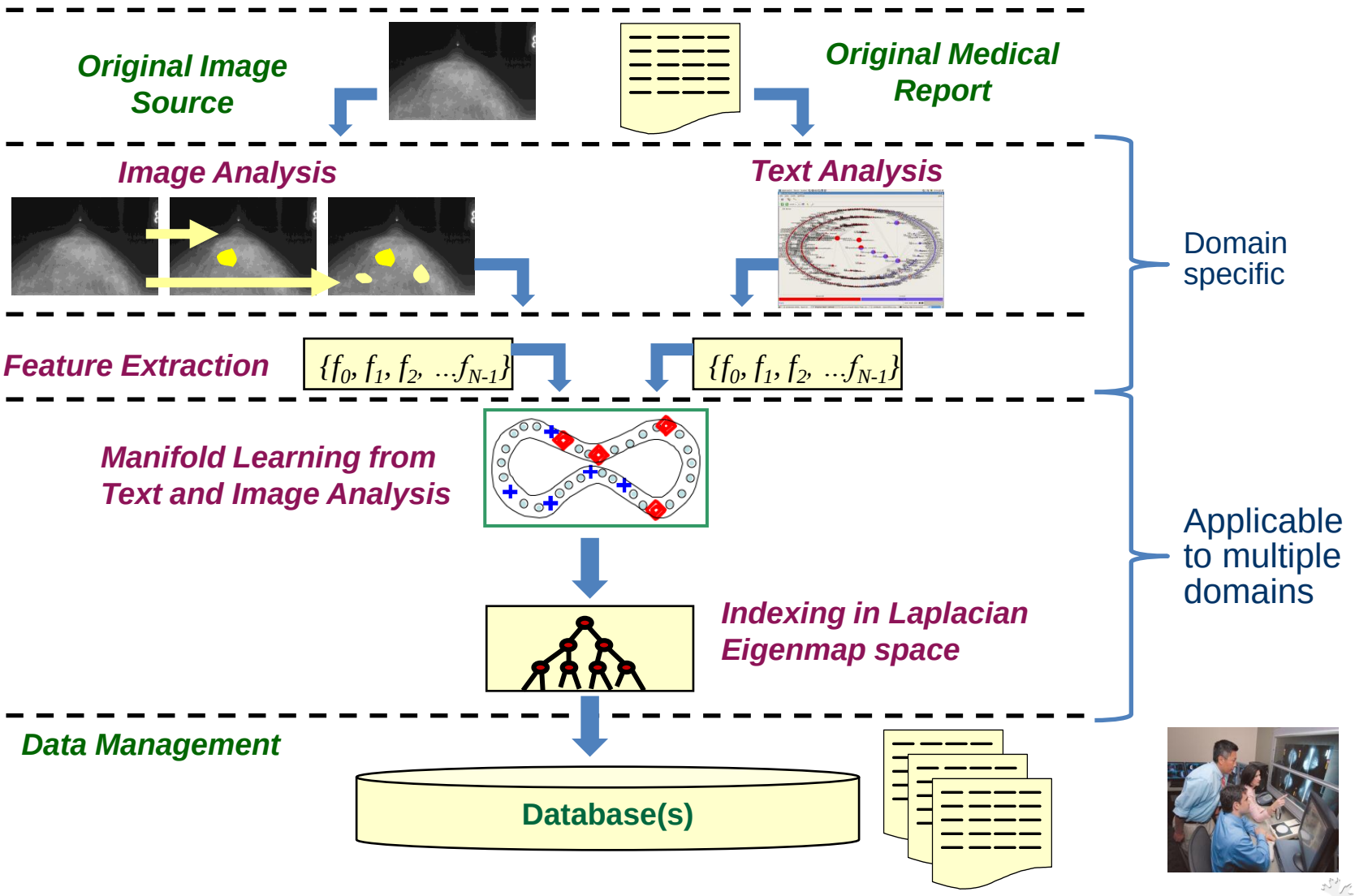
Develop a comprehensive, flexible, and responsive computing framework that incorporates ability to analyze multimodal data using semi-automated learning environments

Benefit:

Organized, integrated, feature-specific focus on relevant multimodal data for more effective, targeted analysis and decision making

* Research sponsored by the Laboratory Directed Research and Development Program of Oak Ridge National Laboratory, managed by UT-Battelle, LLC, for the U.S. Department of Energy.

DAMSEL concept: Text and image analysis in machine learning environment



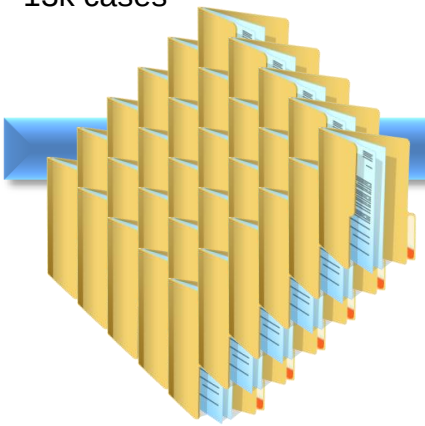
Text processing and features extraction

Objectives

- Leverage ***human expertise*** to characterize and classify the data
- Enhance statistical analysis with evolutionary algorithms to learn domain-specific, significant textual features
- Develop new classification learning algorithm based on evolutionary algorithms
- Provide basis for longitudinal analysis in order to find trends or precursors

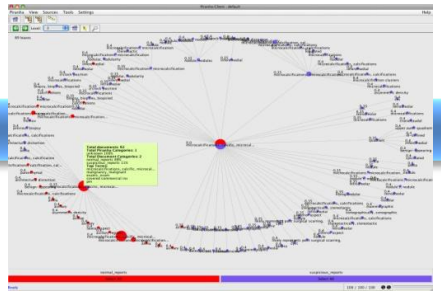
Database

- Text reports provided by the University of Chicago
- Total: 61k reports for 13k cases



Initial processing

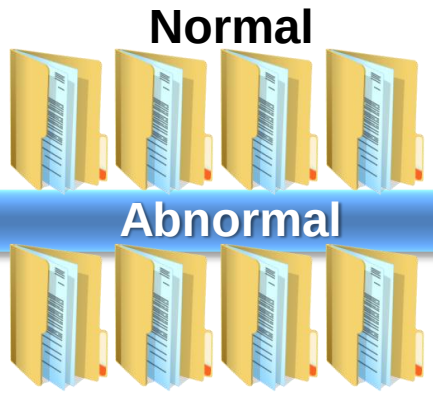
- Stopword removal
- Phrase extraction



Features extracted

- No mass lesions evident"
- "Appearance of soft tissue densities"
- "Atypically located intramammary lymph node"

Statistical Analysis and Classification Learning Using Evolutionary Algorithms



Textual Features

Features extracted

- **Normal Reports:** "no & malignancy," "no & masses"
- **Abnormal Reports:** "core & biopsy," "spot & magnification"

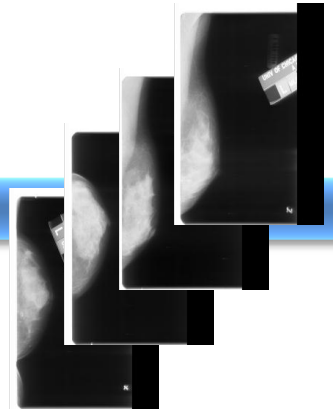
Image processing and features extraction

Objectives

- Select suitable image processing algorithms to perform feature extraction
- Follow the Breast Imaging-Reporting and Data System (BI-RADS) specifications, and develop one scalable algorithm for each feature it describes
- Develop new techniques around the Fractal Segmentation concept
- Implement the algorithms on GPU platform toward large database processing

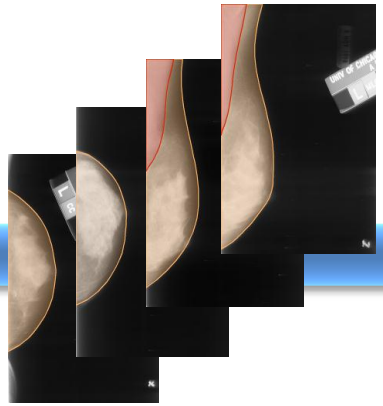
Database

- Images provided by the University of Chicago
- Total: 54k images for 13k cases

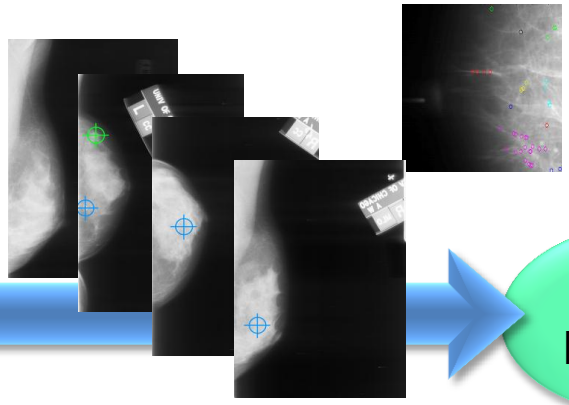


Initial processing

- Tissue segmentation
- Morphological assessment



Calcification, Mass, and Architectural Distortion Detection



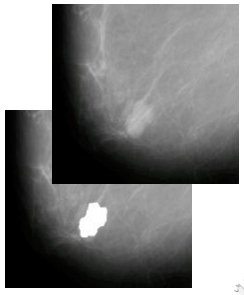
Images Features

Features extracted

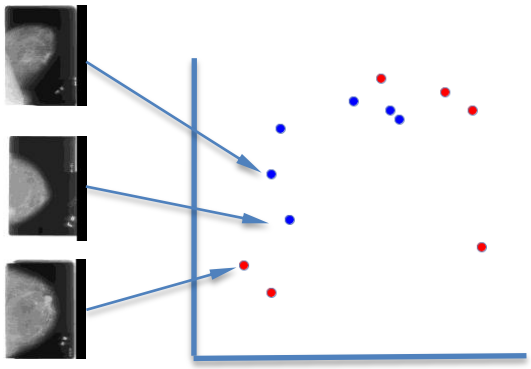
- Number of images (CC & MLO)
- Breast tissue and pectoral muscle segmentation
- Dimensions, asymmetry, texture, etc.

Features extracted

- **Calcification:** number / distribution / contrast / cluster size / etc.
- **Mass:** shape / margin / density / texture / etc.
- **Architectural Distortion:** texture distortion



DAMSEL biomedical framework—multimodal manifold discovery



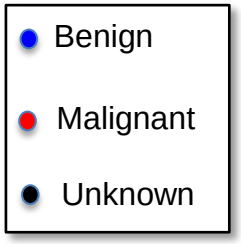
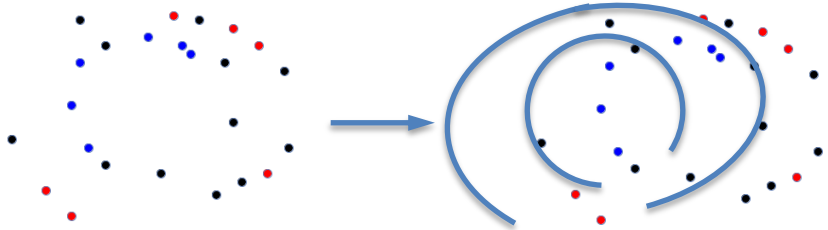


Image Space



Unclassified Points Help Reveal Manifold

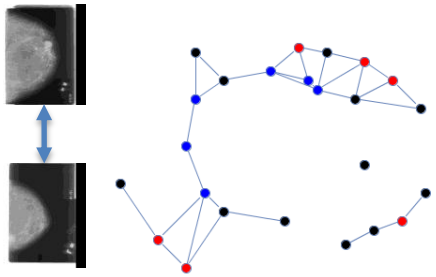
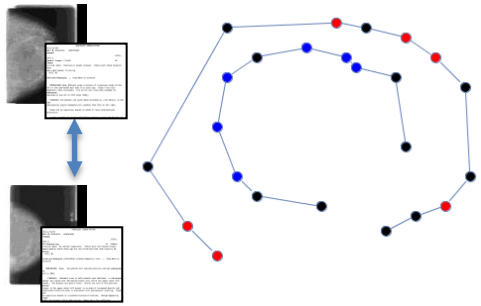
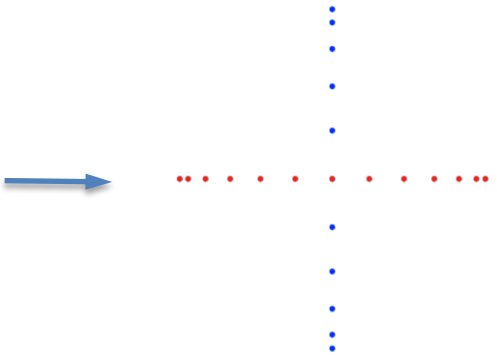


Image Similarity Graph



Similarity Augmented By Cancer-Relevant Text

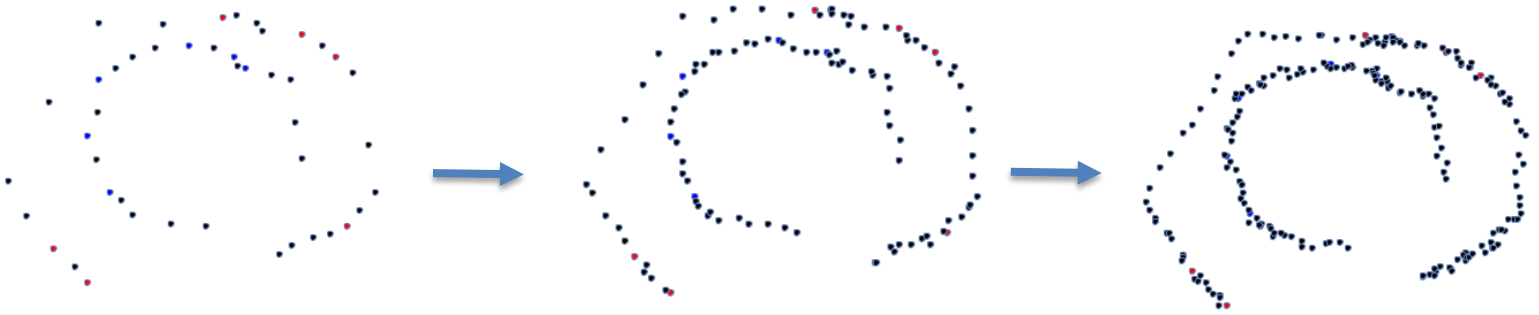


Improved Graph Laplacian-Based Decision Space

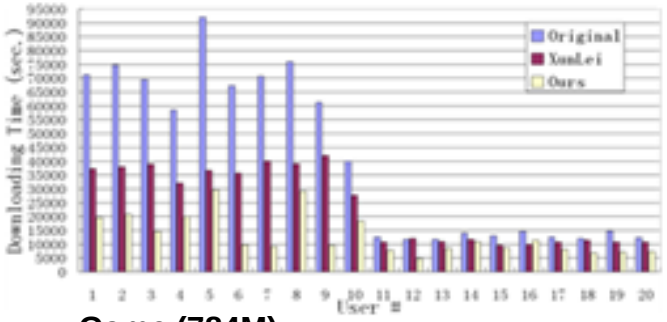
Increasing manifold fidelity

Attempts to significantly increase fidelity can impose great computational demands

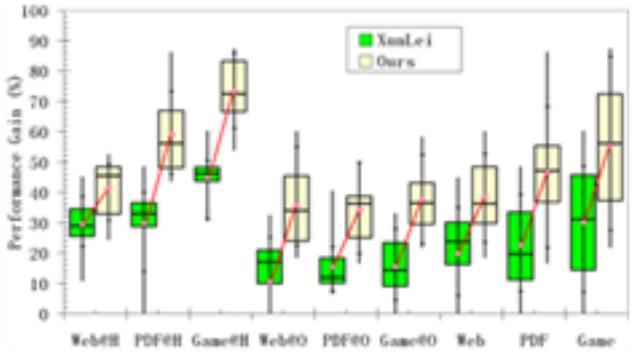
Increasing:	Increases Complexity:		
	Time	Space	Sample
Image/text feature set size	↑	↑	↑
Image/text feature complexity	↑	—	—
Patient sample set size	↑	↑	N/A
Thresholded, unweighted sparse graph → weighted dense graph	↑	↑	N/A

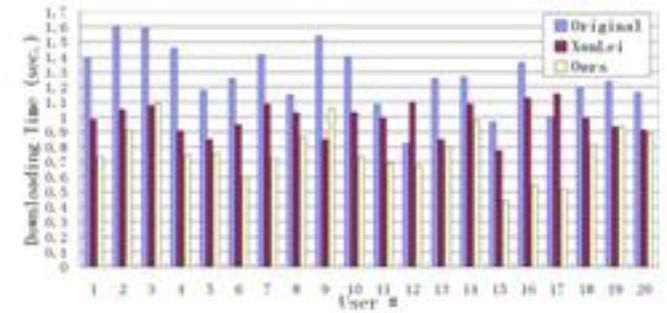


Multimodality data fusion

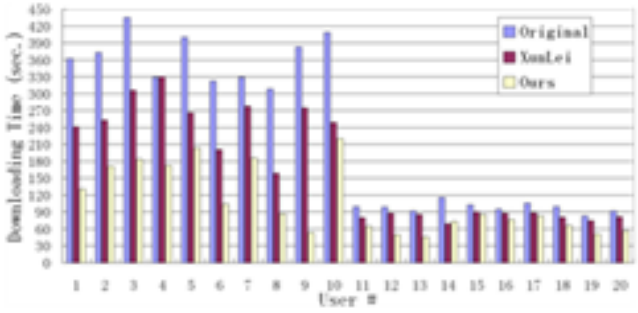


Game (784M)





Web (10.6K)



PDF (3.49M)

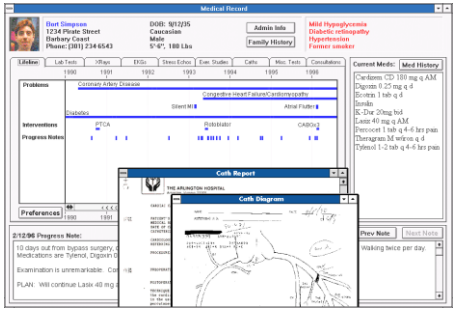
Keyword Extraction Method	Precision	Recall	F-rate
TF × IDF	0.210	0.312	0.251
Yahoo! Term Extraction	0.231	0.362	0.282
Wikify!	0.285	0.421	0.340
Community detection	0.312	0.435	0.373
Our method	**0.456**	**0.513**	**0.483**

Slide provided by Songhua Xu

Computer tools for medical analytics and visualization (combine M&S, KD, and Viz)

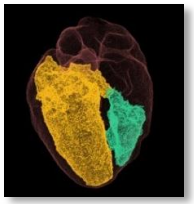
Patient-centered care

Patient medical record



Patient record

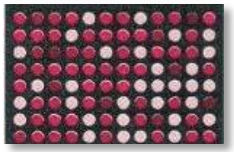
Data sources



Imagery

Tissue biopsy

Microarray data



Databases/system architecture

System architecture integrates databases

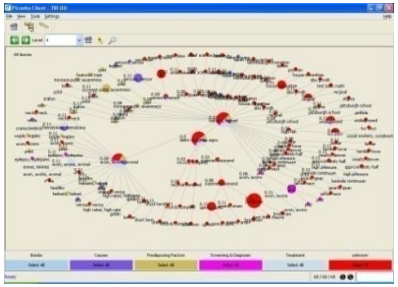
Advanced analysis and visualization

Image retrieval, processing and integration

Visualization

Knowledge discovery engine

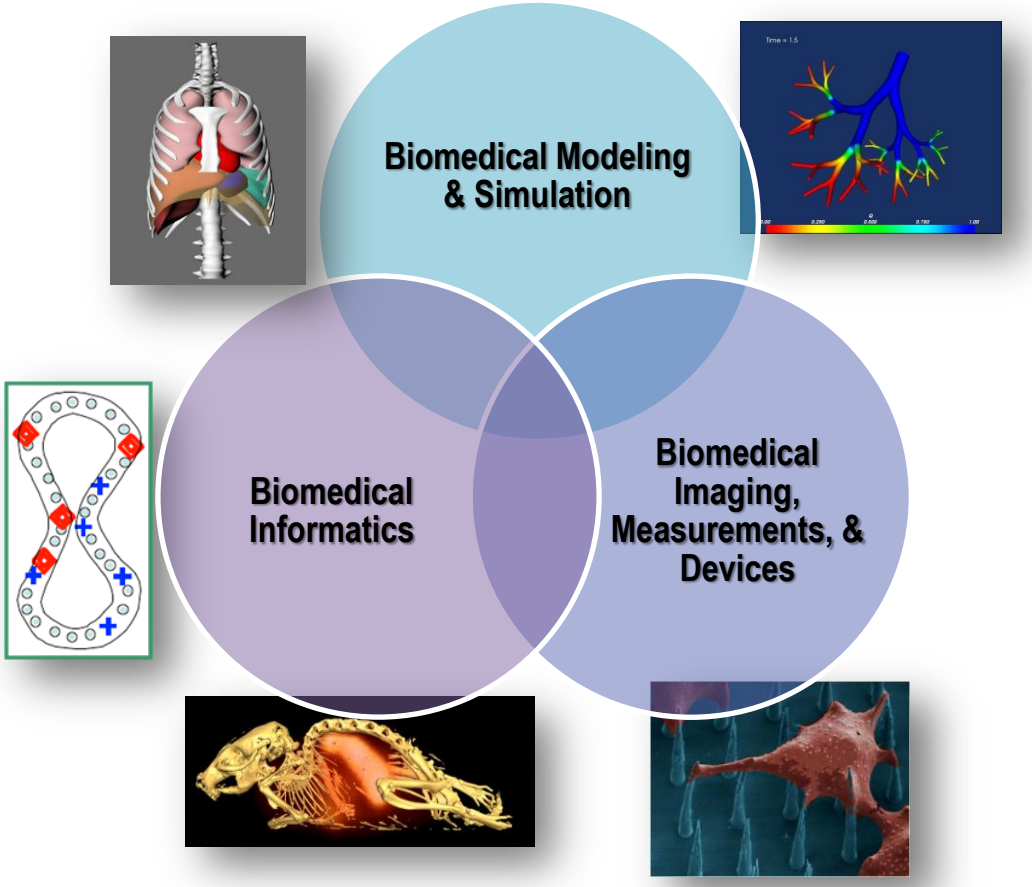
Data analytics



KD output

Biomedical Science and Engineering Center

Mission: To act as a catalyst and national resource for interdisciplinary biomedical research addressing challenges in key areas:



OBJECTIVES

- Establish a framework to identify critical research directions and facilitate interdisciplinary collaborations between academia, government agencies, the medical community, industry, and the ORNL research community
- Foster innovation and vital technological breakthroughs in key areas of the biomedical sciences
- Facilitate and organize an annual conference, providing a platform for interactions with nationally recognized biomedical science and engineering experts. Outputs from this conference will serve as inputs into roadmapping activities at NIH, DOD, and other medically related entities/efforts
- Establish and provide mentoring and educational opportunities for minority and underrepresented communities

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BSEC key activities

BSEC
Biomedical Science and Engineering Center
OAK RIDGE NATIONAL LABORATORY

Conferences

1st Annual BSEC Conference, March 18–19, 2009 at ORNL

http://computing.ornl.gov/cse_home/cms/conference/index.shtml

BSEC 2010, May 25–26, 2010 Oak Ridge, TN

https://www.ornl.gov/bsec_conferences/2010/Index.shtml

BSEC 2011 March 16–17, 2011 Knoxville, TN

Seminars

Nationally and internationally known speakers

BSEC members

Education

Capstone Design Program (Joint BSEC/ORNL/UTK program)

- Student internships
- Mentoring program
- Joint appointments (faculty)
- Core universities

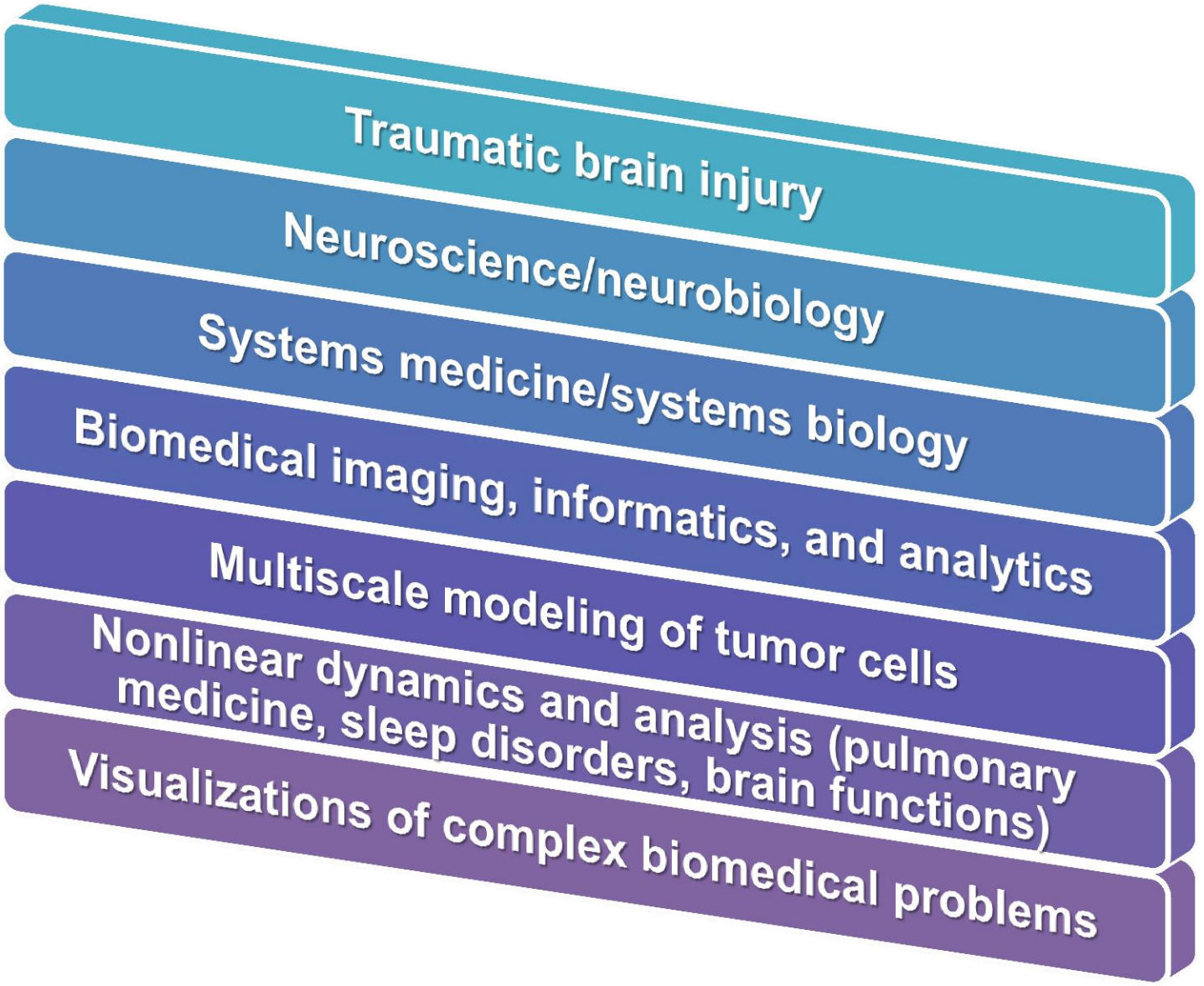
Collaborations and Partnerships

Universities

Federal agencies

Private sector

Growth opportunities and future directions



Contact

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