The Cancer imaging Phenomics Toolkit (CaPTk)

Christos Davatzikos, on behalf of the team

Penn
University of Pennsylvania

Center for Biomedical Image Computing and Analytics

Computational Breast Imaging Group
Penn Image Computing and Science Lab
Penn Statistical Imaging and Visualization Endeavor
Section for Biomedical Image Analysis

Participating PIs

Computational Breast Cancer Imaging R01 (NCI; Kontos, Conant, Schnall, W

R01 (NINDS; V Brem)

Computational Neuro-oncolo INDS; Davatzikos and O

R U24/NCI:
aging Phenomics

(NCI; Mankoff, Doot, Pryma, Fan)

Image Segmentation and Analysis R01 (NBIB; Yushkevich)

B ging Biostatistics R01 (NINDS; Shinohara)

Two Major Goals

- To leverage a rich family of advanced image computing algorithms

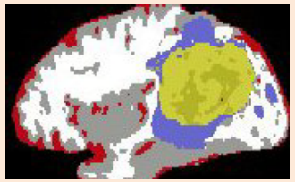
- To leverage extensive and long-standing collaborations with clinical teams who have provided input in the development of the algorithms, as well as data for training and validation of models

First Level

Image Analysis Algorithms

Segmentation:

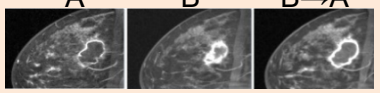
Regions of Interest (ROIs)

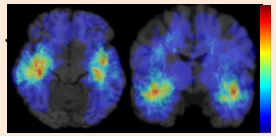


Registration:

- Measure change with time:

A B B→A

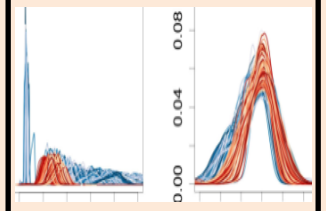




Common vs. Rare

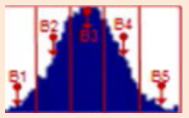
Image Harmonization:

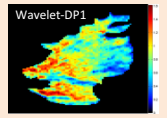
Before After



Feature Extraction:

Texture, histogram, dynamics, spatial pattern





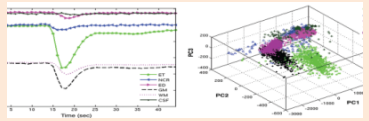


Image Operations:

- DICOM access
- Format conversion
- Intensity normalization
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ITK

CaPTk Radiomic Panel

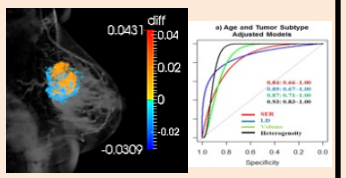
Open-CV

Feature Synthesis and Integration via Machine Learning

Second Level

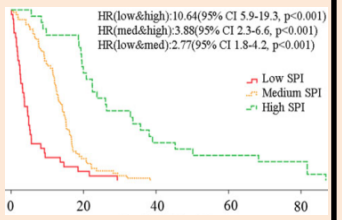
Output Modules and Outcomes

Precision Diagnosis, Risk Estimation:



Breast Density Factor

Predictive models:



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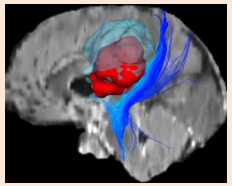

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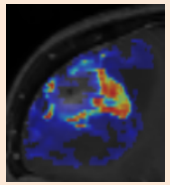

Infiltration

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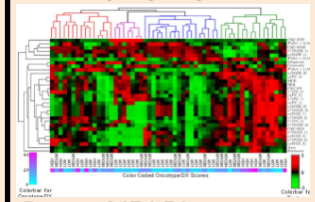

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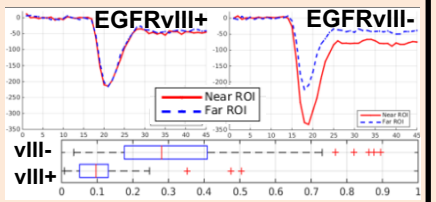

Imaging Signatures of GBM mutations

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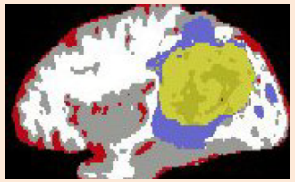

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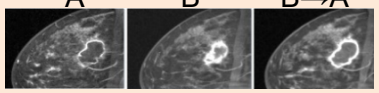

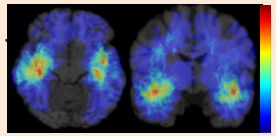

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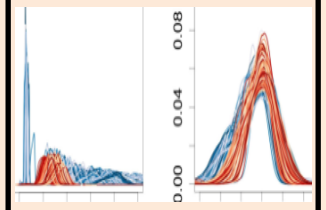

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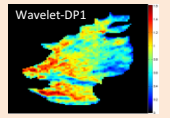

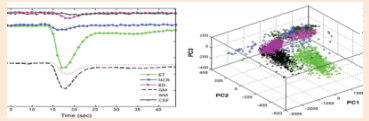

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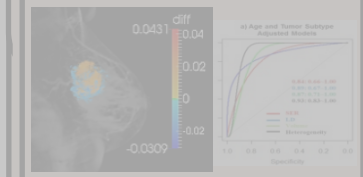

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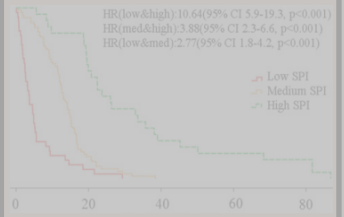

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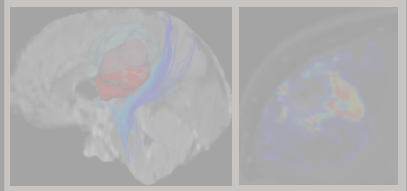

Connectomics Infiltration

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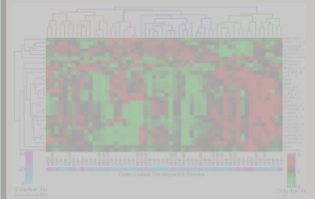

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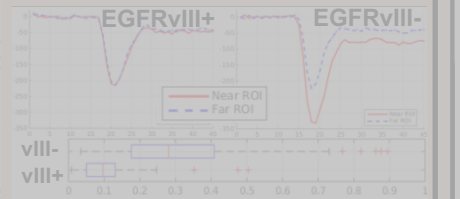
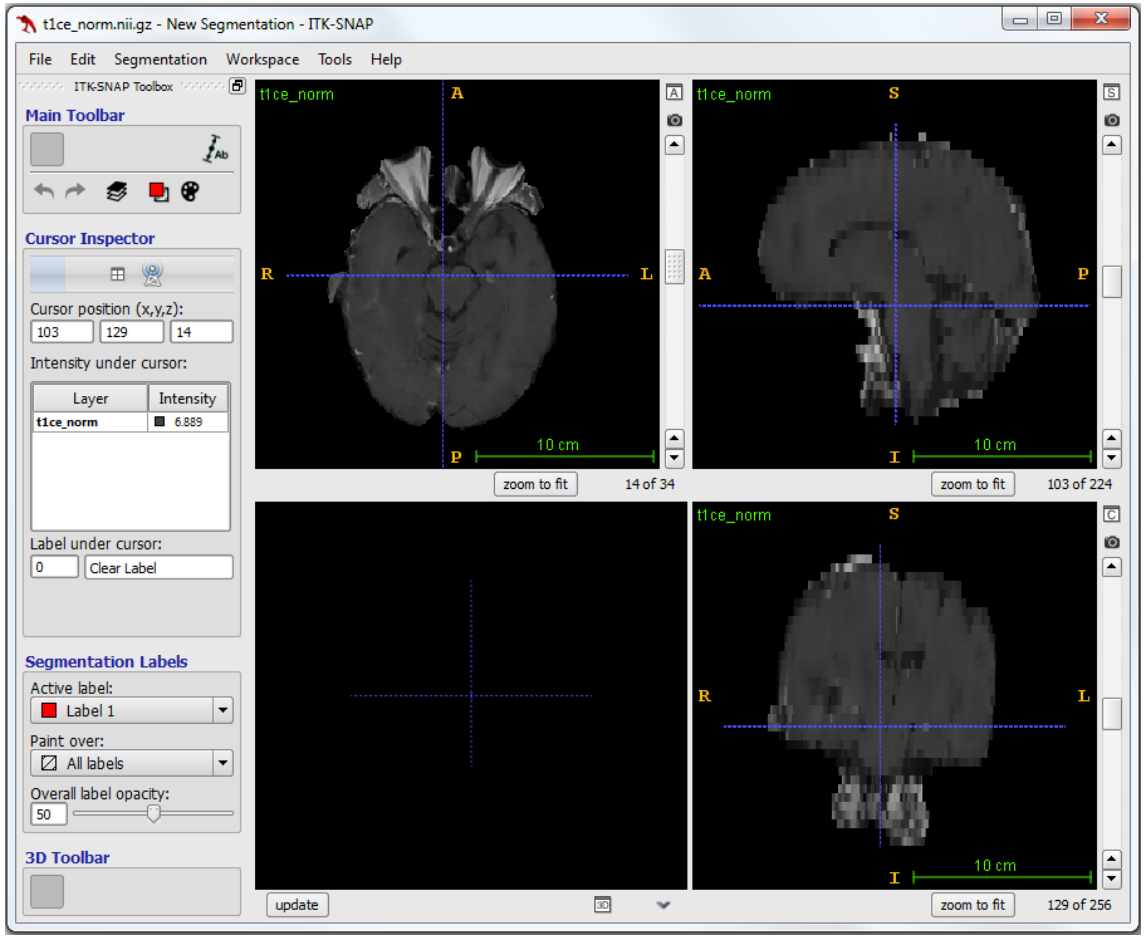


Imaging Signatures of GBM mutations

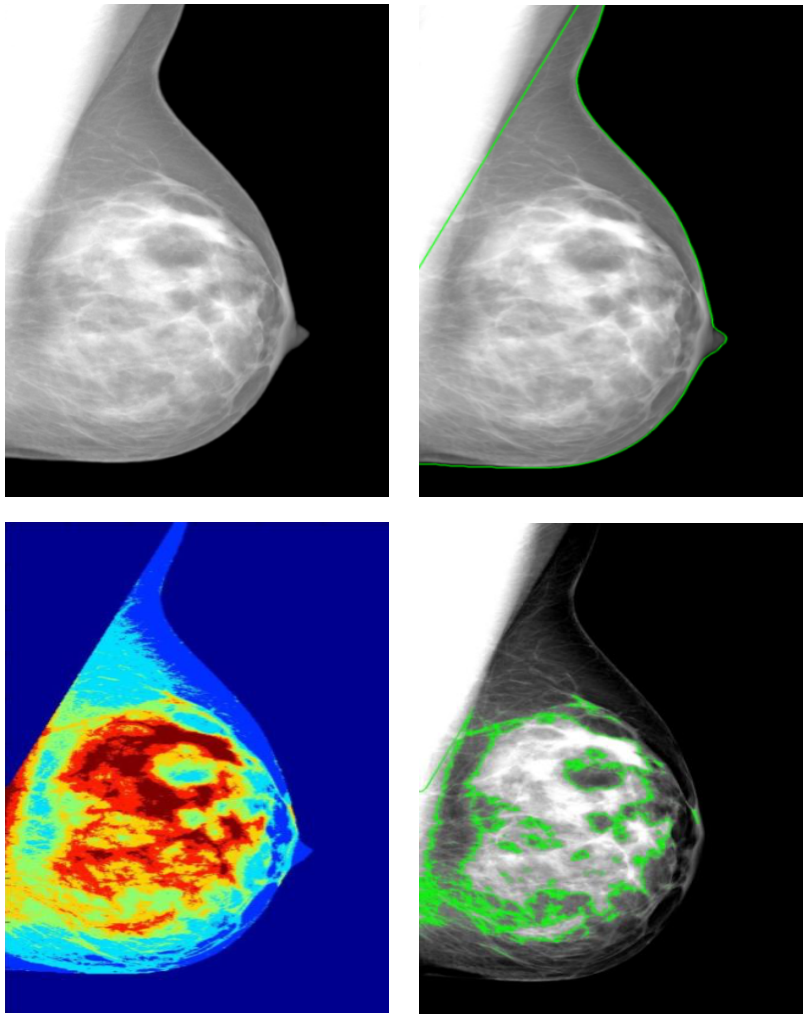
ITK-SNAP



Screenshot of ITK-SNAP's interface

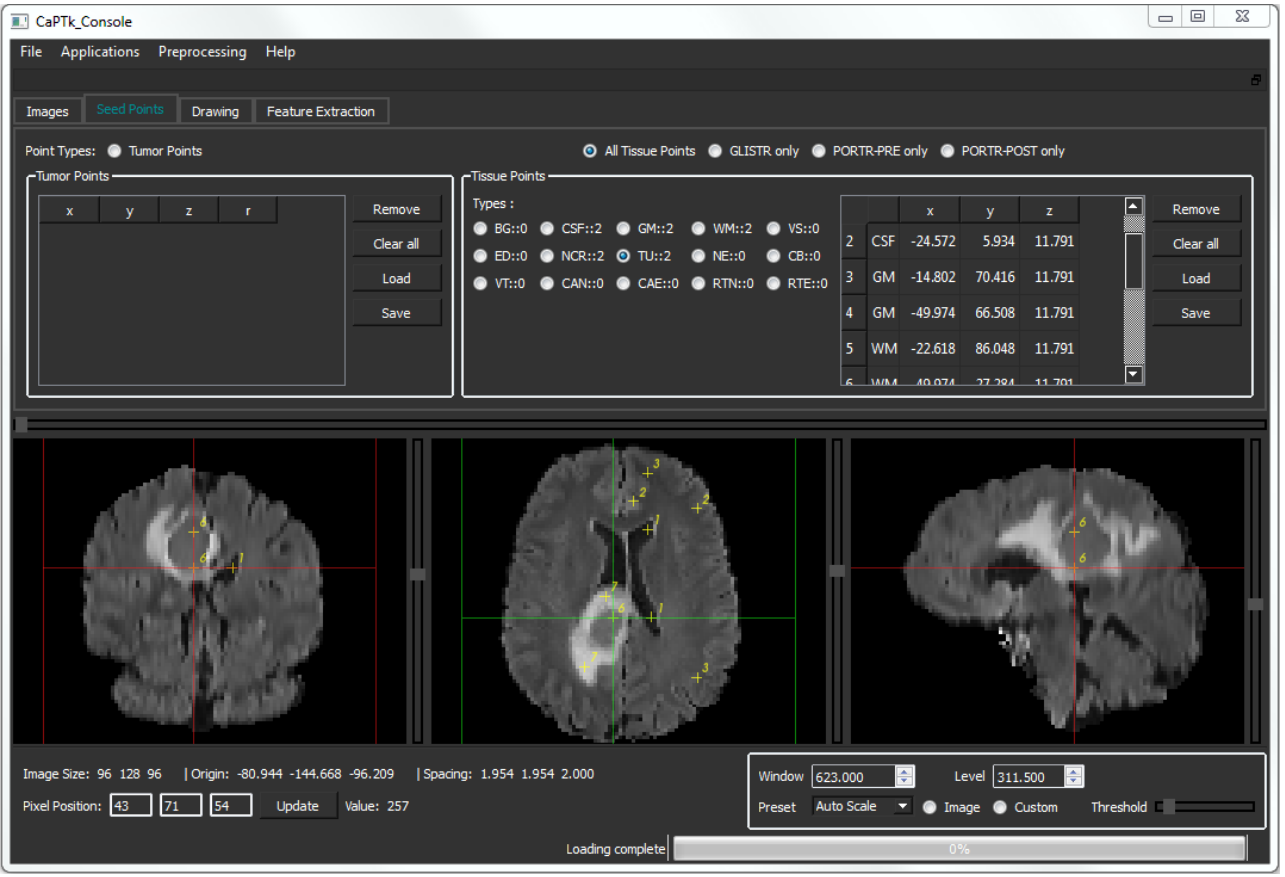
- Support for color, multi-channel, and time-variant images
- Segmentation done using Random Forest and Level Sets algorithms
- Transfer of data between ITK-SNAP and CaPTk is seamless – giving users the option to use the former's segmentation and user interaction functionality with latter's computation capabilities

Breast Segmentation

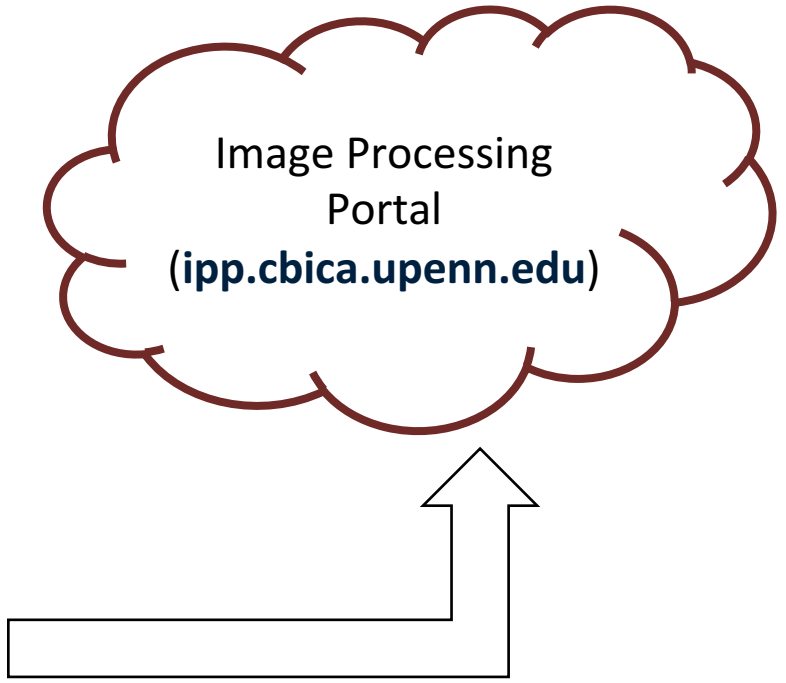


- Fully-automated segmentation of the breast area and the dense breast tissue, estimation of **Percent Density** (PD%)
- Adaptive fuzzy-c-mean (FCM) clustering based on intensity histogram and acquisition parameters
- Well calibrated versus radiologists estimates [9] demonstrated associations to breast cancer risk [10] for raw and processed FFDM.

GLISTRboost Segmentation



Initialize seed points for the MICCAI BRATS 2015 award-winning GLISTRboost method using CaPTk Console



Generative segmentation

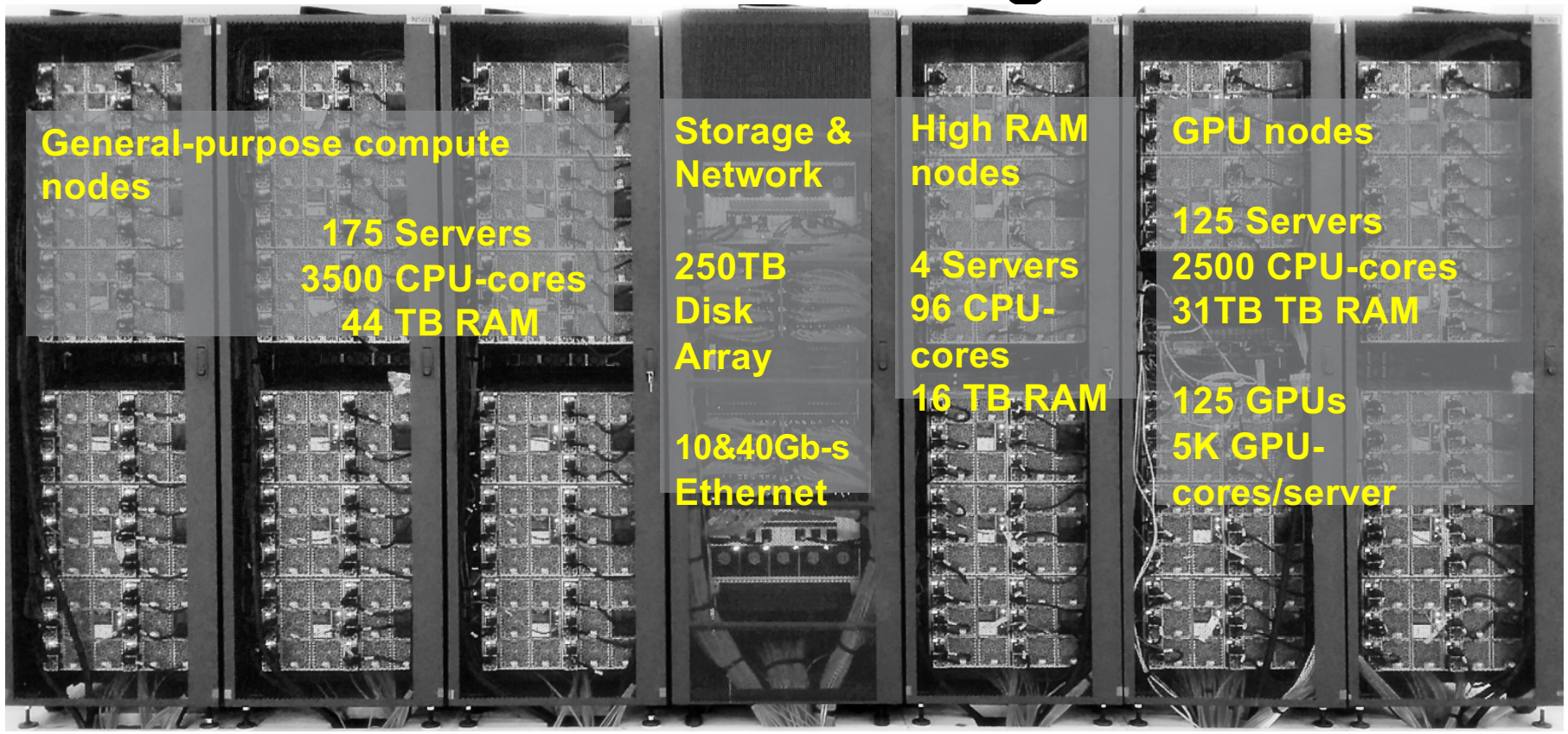
⇩

Discriminative population based refinements

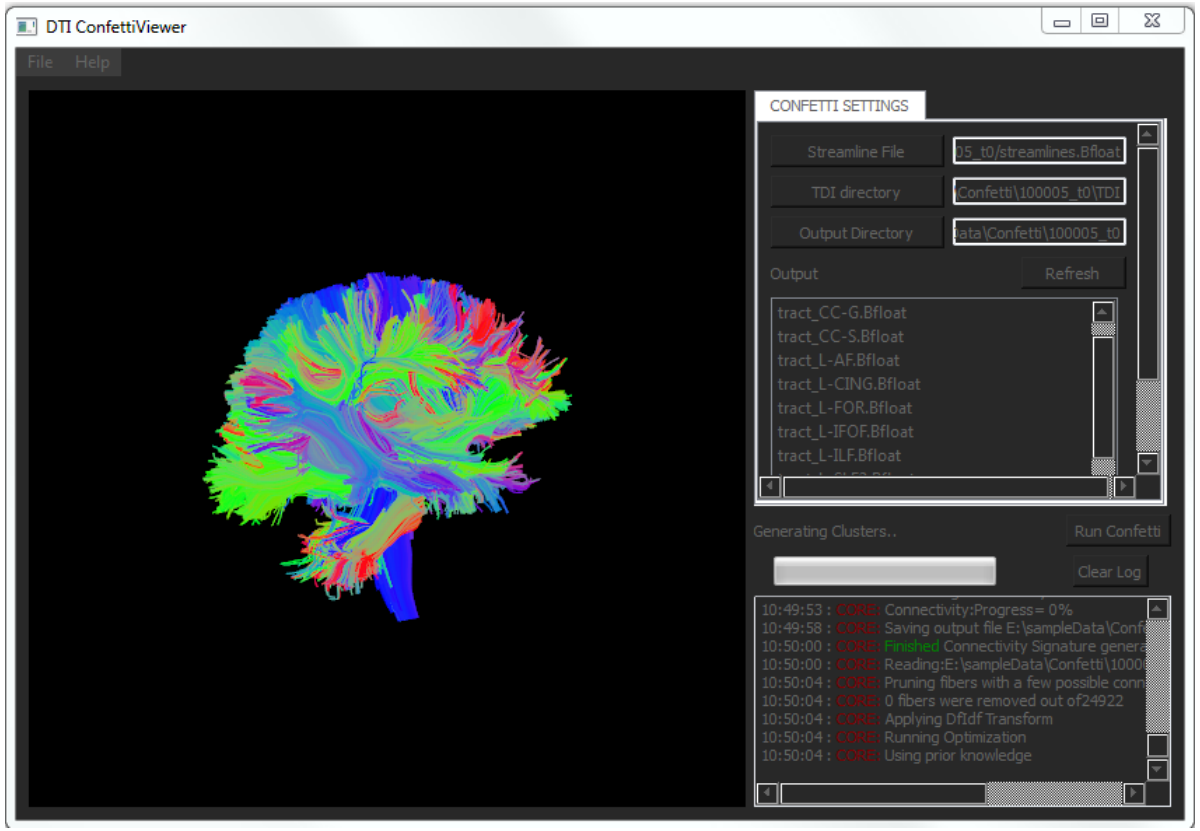
⇩

Bayesian personalized refinements

Web Portal for Compute-heavy CaPTk Functions: CBICA cluster via high-end NIH instrumentation grant:



Confetti – Visualizing Fiber Tracts



Confetti interface is dedicated for fiber tract visualization and it is integrated with CaPTk Console

- Advances in tractography enhance neurosurgical planning, but are limited by edema, mass effect, and tract infiltration
- Confetti facilitates automated identification of all tracts (including eloquent tracts) without manual drawing of ROIs, making the tracts robust and replicable
- Confetti enhances the primary objective of neurosurgery: maximal safe resection in the presence of tumor edema and infiltration

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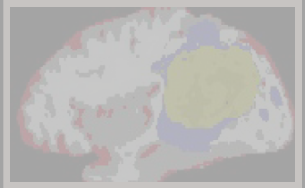

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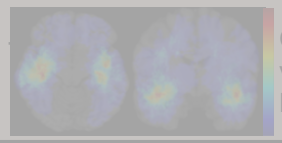

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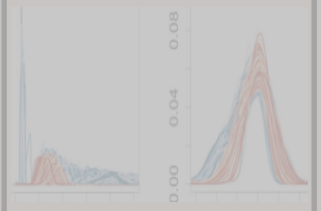

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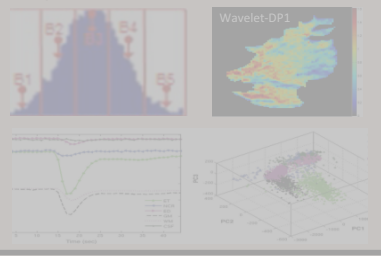

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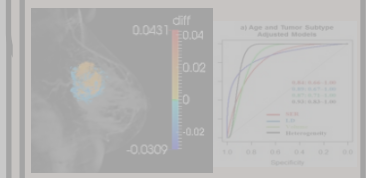

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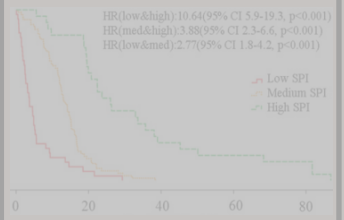

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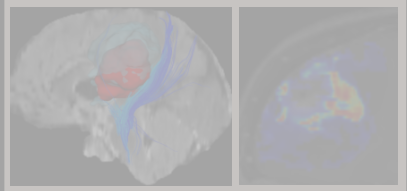

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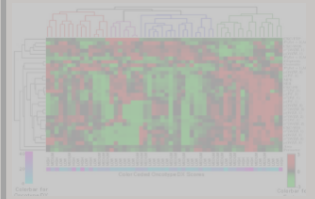

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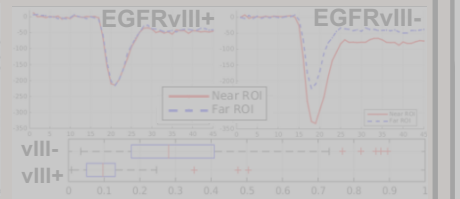
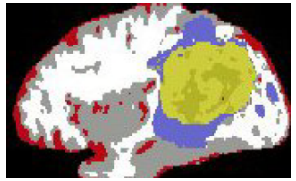


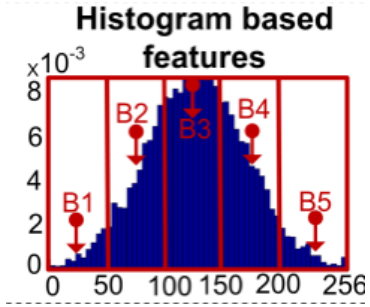
Imaging Signatures of GBM mutations

CaPTk Radiomic Panel

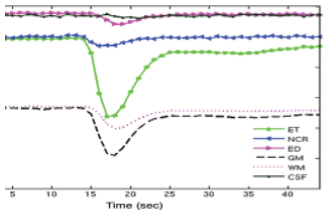
- Segmentations: volumes and signals within ROIs

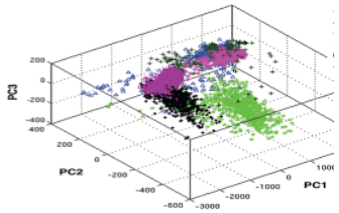


- Normalized histograms of different protocols; optimized binning

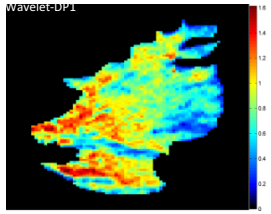


- Kinetics

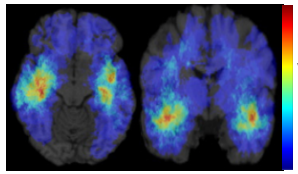




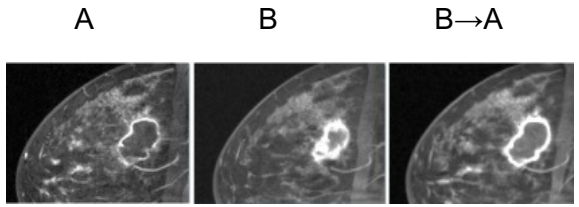
- Textures



- Spatial patterns/distributions



- Parametric maps from longitudinal scans



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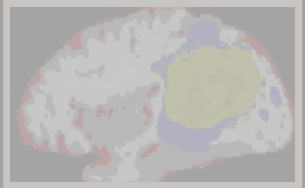

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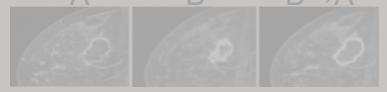

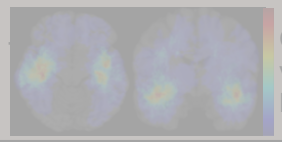

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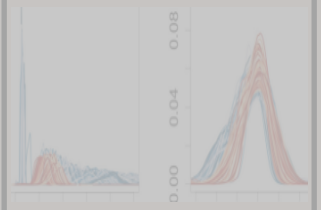

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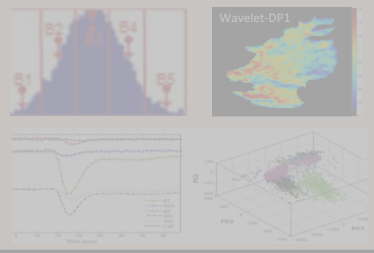

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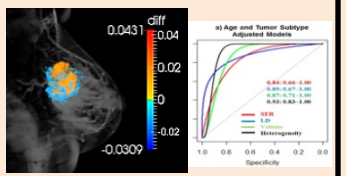
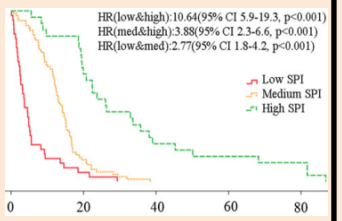
Output Modules and Outcomes

Precision Diagnosis, Risk Estimation:



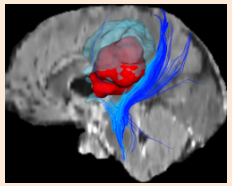
Breast Density Factor

Predictive models:

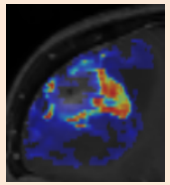


Kaplan-Meier Estimator

Personalized Treatment:

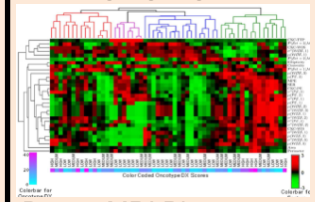


Connectomics

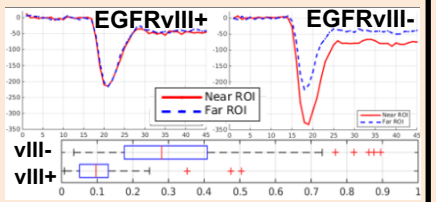


Infiltration

Radiogenomics
Imaging signatures of molecular characteristics:



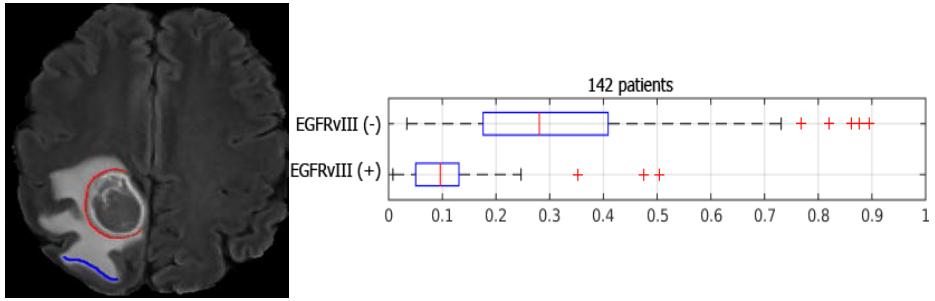
Breast MRI Phenotypes vs. Oncotype DX



Imaging Signatures of GBM mutations

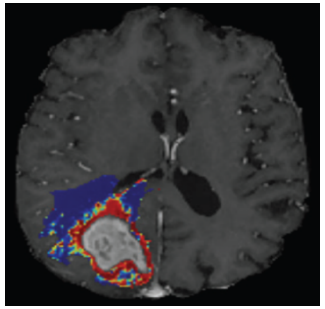
Computational Neuro-Oncology

Imaging Signatures of Molecular Characteristics



Bakas et al, Clinical Cancer Research 2017

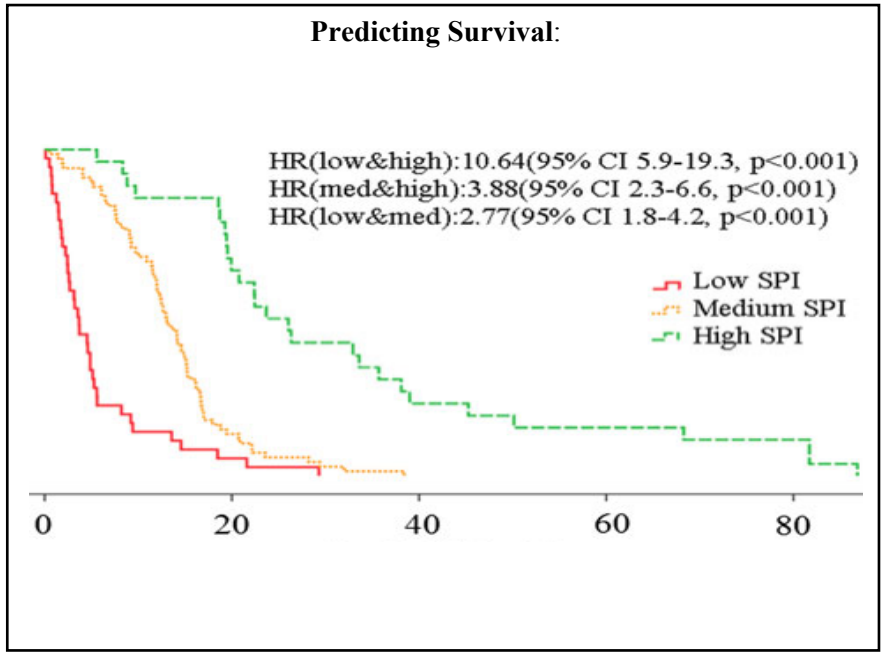
Predicting Infiltration and Recurrence



Akbari et al., Radiology, 2014
Akbari et al., Neurosurgery, 2016

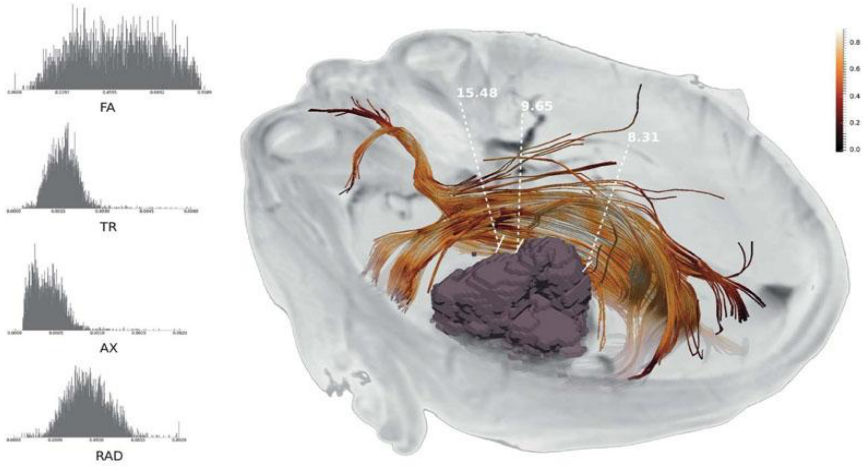
Predictors of clinical outcome

Predicting Survival:

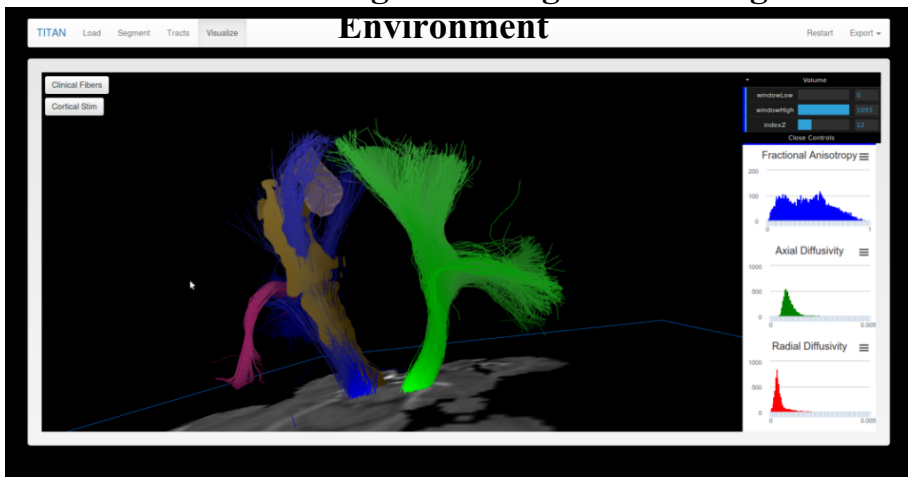


Brain Connectomics

Peri-lesional Effects of GBMs

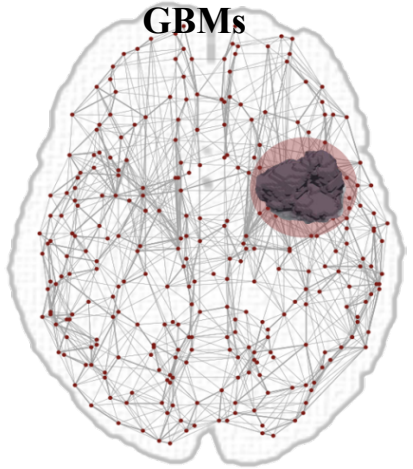


Web-based Integrated Surgical Planning Environment

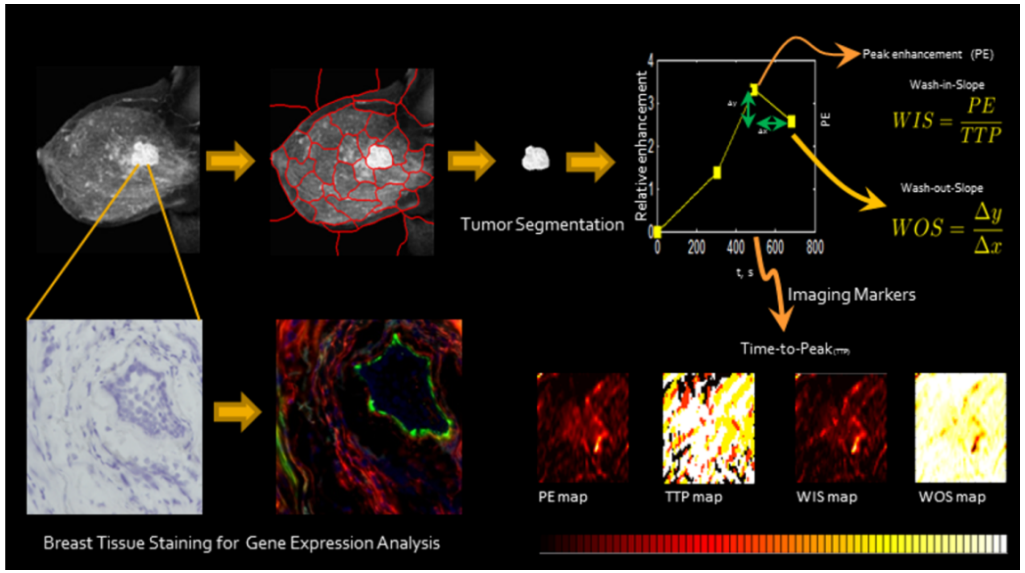


- Automated atlas-based tract extraction (using connectivity signatures instead of shape help address mass effect)
- Edema invariant tractography (using multicompartment models fitted to multishell imaging)
- Tumor connectome (effect of tumor on distant regions, regional vulnerability and functional rerouting)

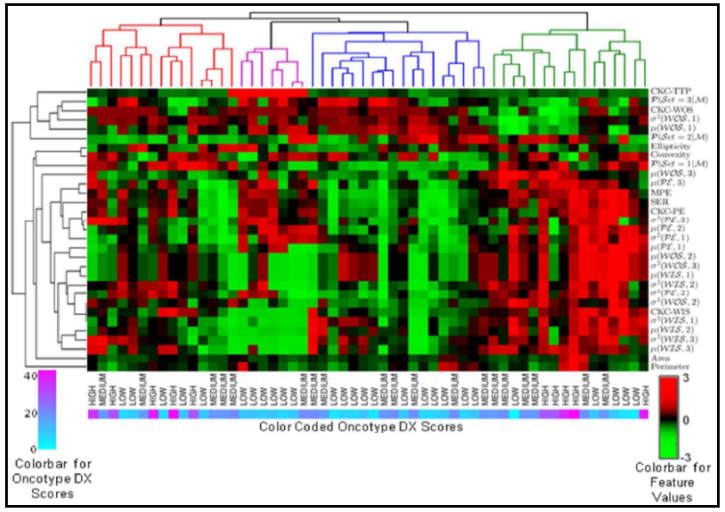
Global Effects of GBMs



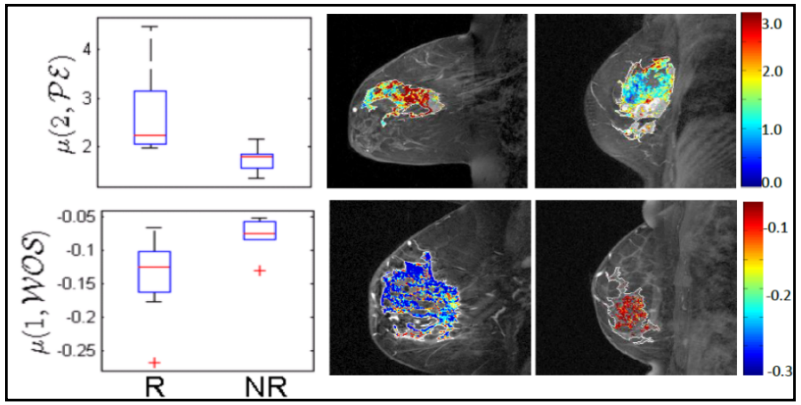
Radiomic Breast Cancer Phenotypes



Ashraf et al., IEEE TMI 2013; Mahrooghy et al. IEEE TBME 2015



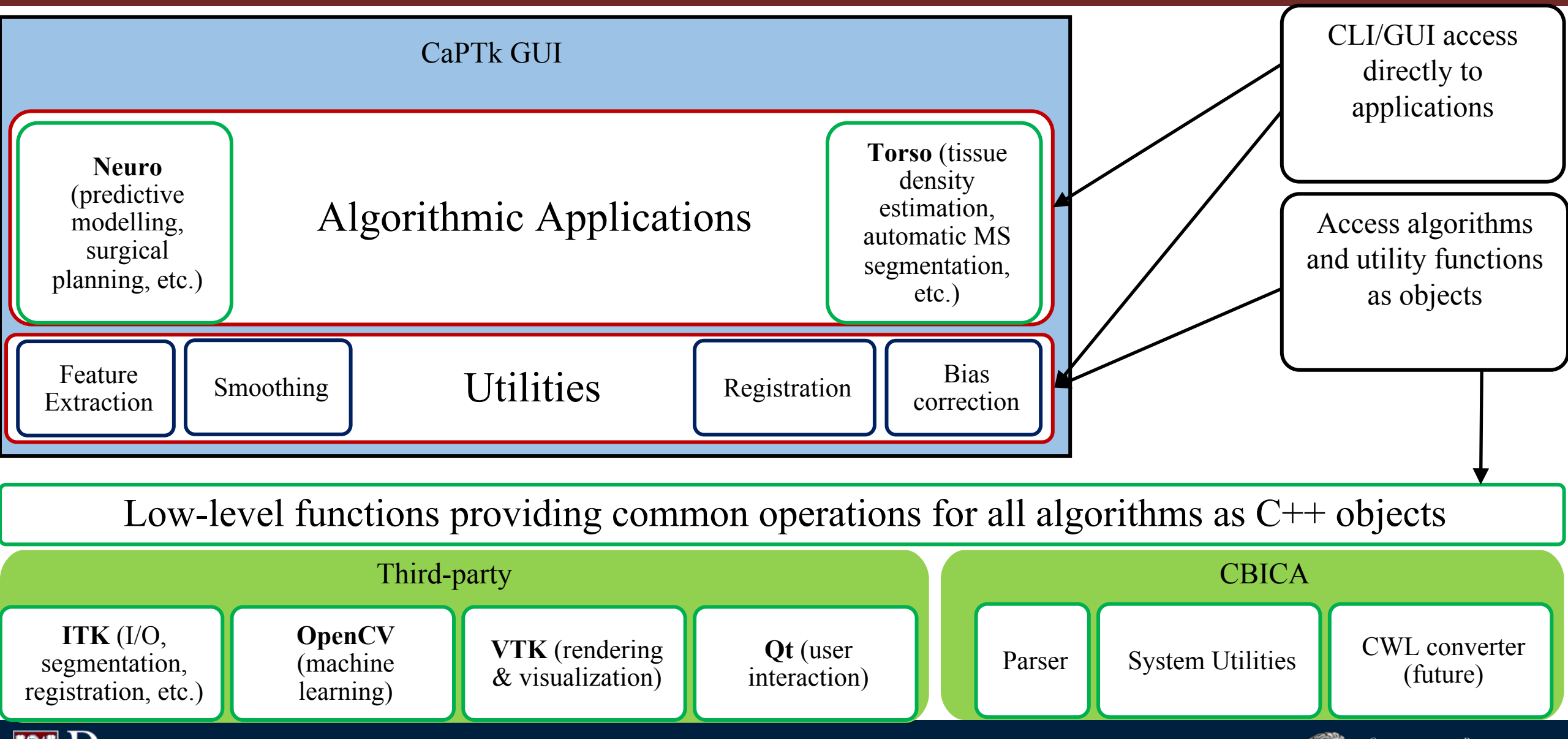
Intrinsic Imaging Phenotypes for Breast Cancer <u>Prognostic</u> and <u>Predictive Value</u>



Breast Cancer Phenotyping via Imaging:

- Segmentation and multi-parametric feature extraction
- Identification of <u>intrinsic</u> phenotype patterns
- Prognostication and treatment response prediction

Software Architecture Overview



Installation

- Only 64-bit machines supported due to processing requirement
- Installers are designed to work as double-click and install
- Windows and Linux installers are available and macOS to be ready soon
- The entire CaPTk (console and all applications) will also be available as docker images soon

Operating System	Version	Installer System
Windows	7+	MSI
macOS	Snow Leopard+	DMG
Ubuntu	14.04+	DEB
centOS	6+	RPM

Dependencies

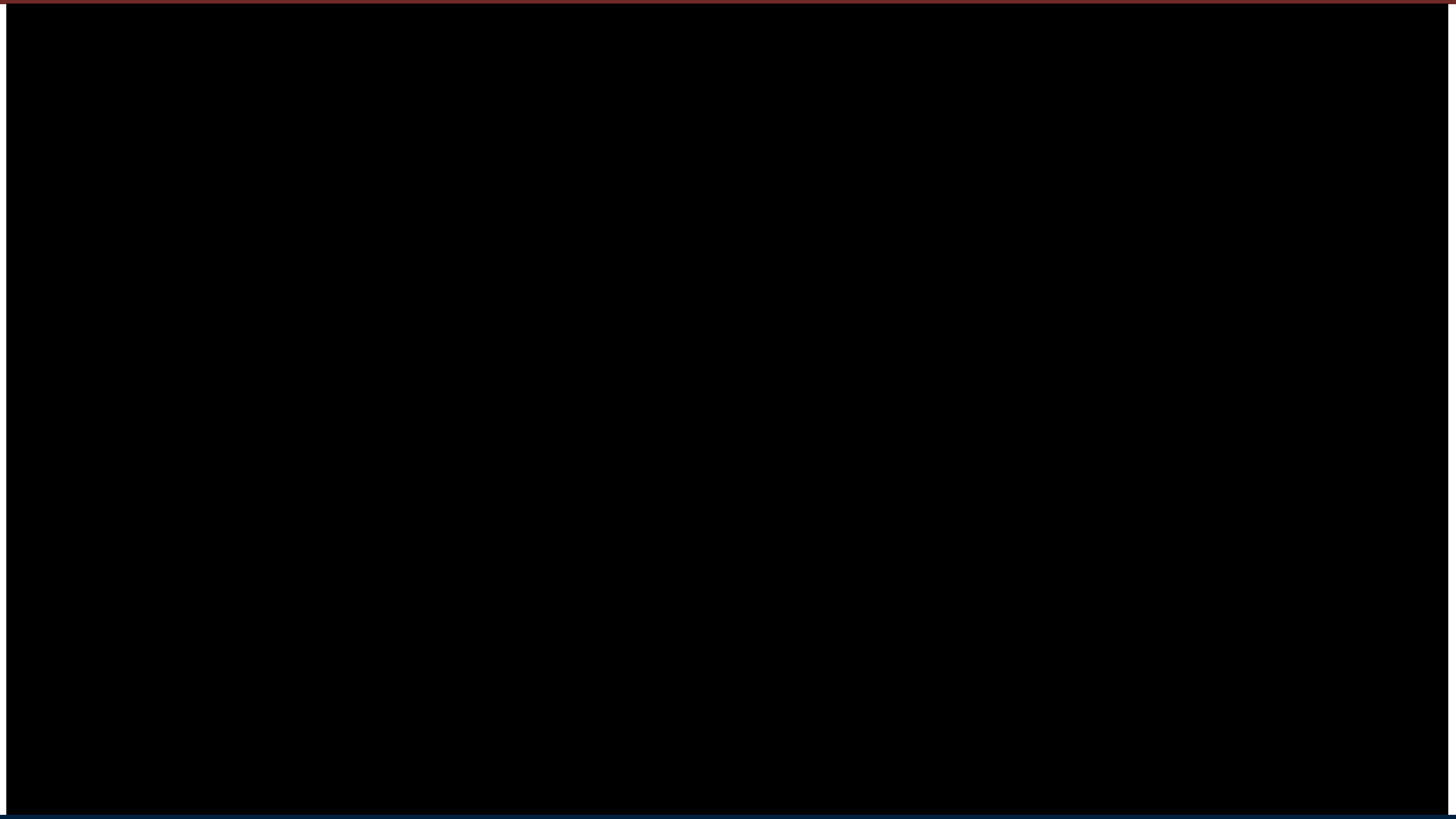
- Core Application (written in C++ for efficiency):

Library	Utility	Reference
Qt	Graphical Framework of application	www.qt.io
Visualization Toolkit (VTK)	Visualization of images, charts, etc.	www.vtk.org
Insight Toolkit (ITK)	I/O, image processing, etc.	www.itk.org
OpenCV	Machine Learning	www.opencv.org

- Different Components (can be C++ or Python):

Library	Utility	Reference
numpy	Higher level math operations	numpy.org
pyqt	User interface of some applications	wiki.python.org/moin/**PyQt**
dipy	Diffusion Imaging	nipy.org/dipy

Video



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