

The Cancer imaging Phenomics Toolkit (CaPTk)

Christos Davatzikos, on behalf of the team

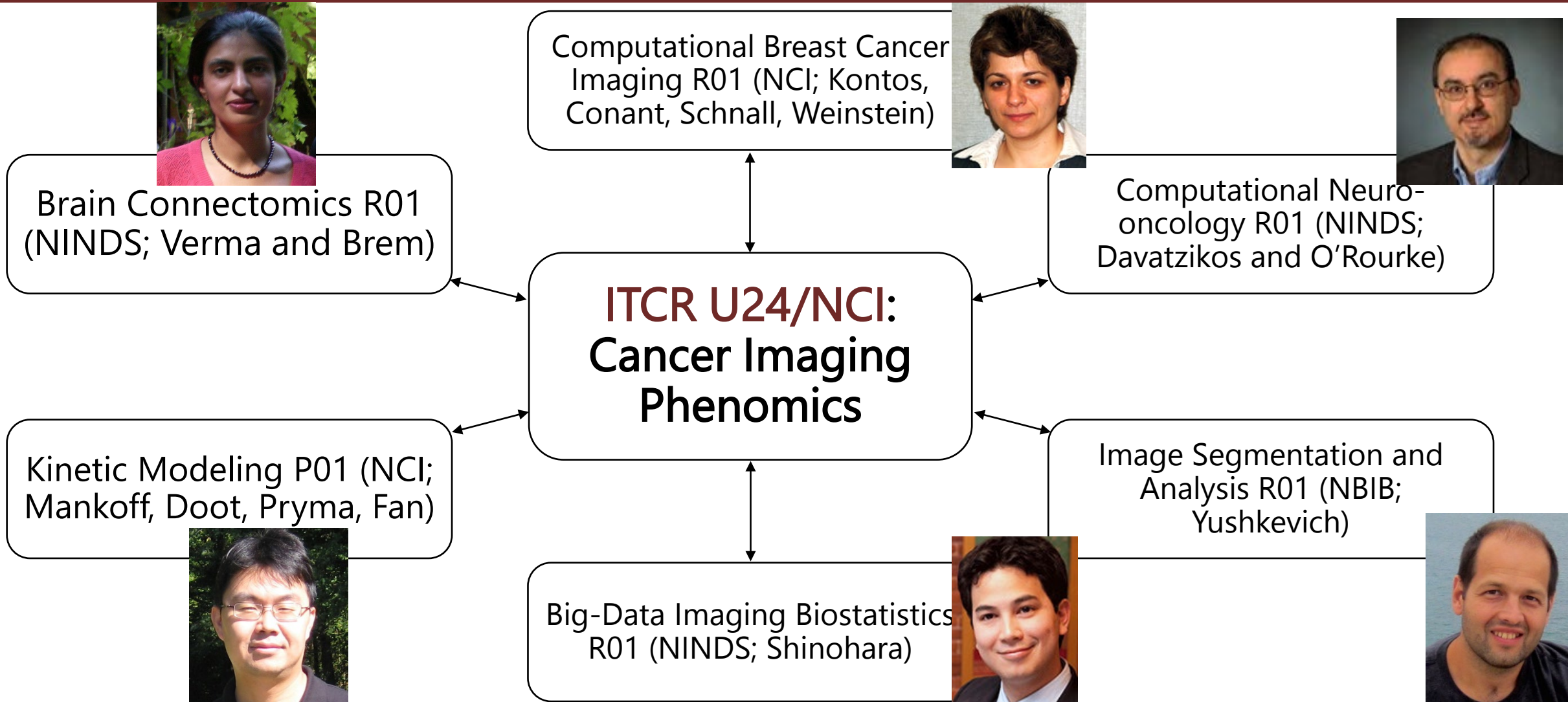


Center for Biomedical Image Computing and Analytics

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



Participating PIs

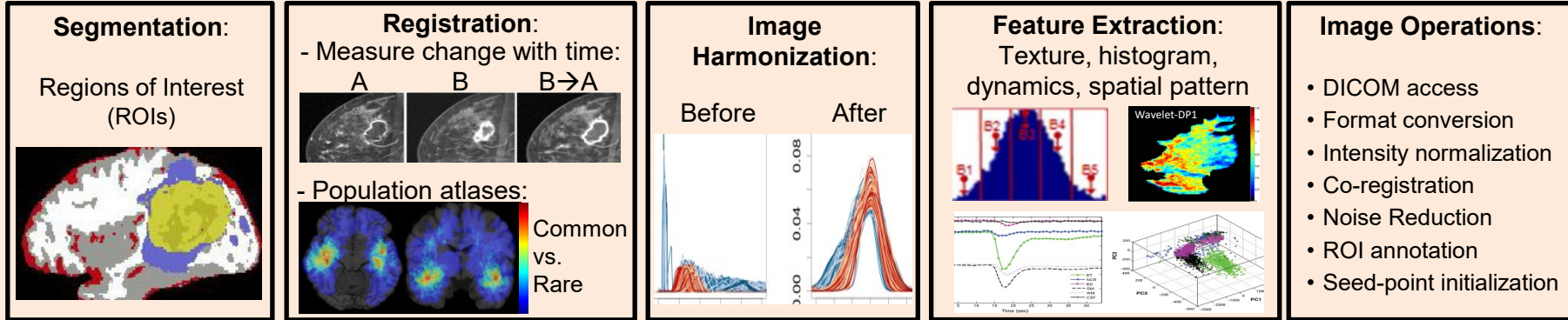


Two Major Goals

- 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



ITK

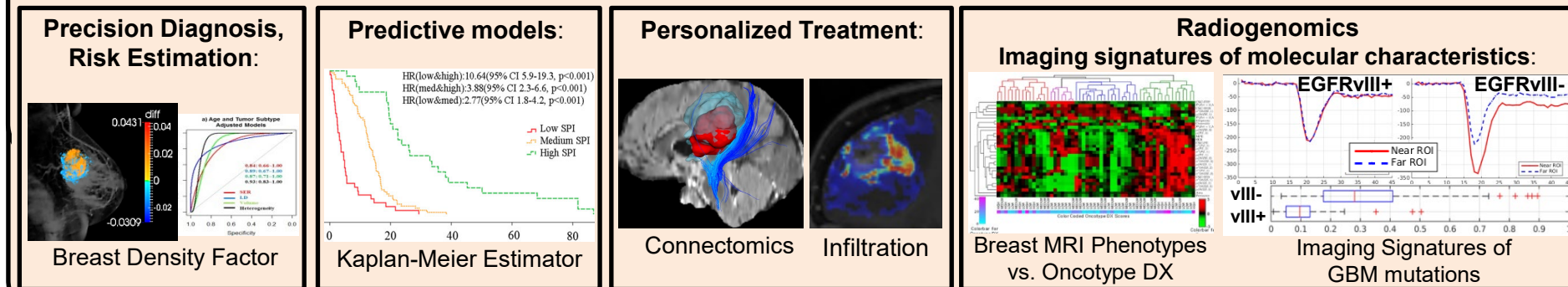
CaPTk Radiomic Panel

Feature Synthesis and Integration via Machine Learning

Open-CV

Second Level

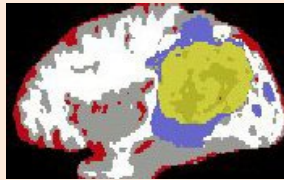
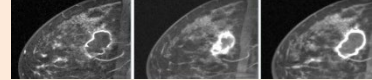
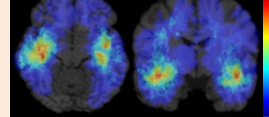
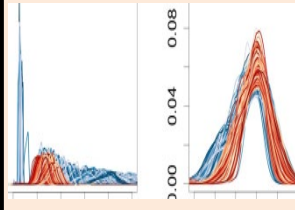
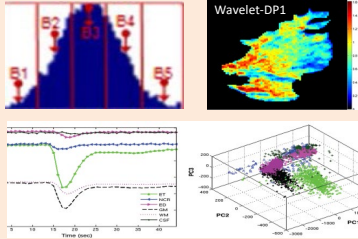
Output Modules and Outcomes



Input Images

First Level

Image Analysis Algorithms

Segmentation: Regions of Interest (ROIs) 	Registration: - Measure change with time: A B B→A  - Population atlases:  Common vs. Rare	Image Harmonization: Before After 	Feature Extraction: Texture, histogram, dynamics, spatial pattern 	Image Operations: <ul style="list-style-type: none">• DICOM access• Format conversion• Intensity normalization• Co-registration• Noise Reduction• ROI annotation• Seed-point initialization
---	--	--	--	--

ITK

CaPTk Radiomic Panel

Feature Synthesis and Integration via Machine Learning

Open-CV

Second Level

Output Modules and Outcomes

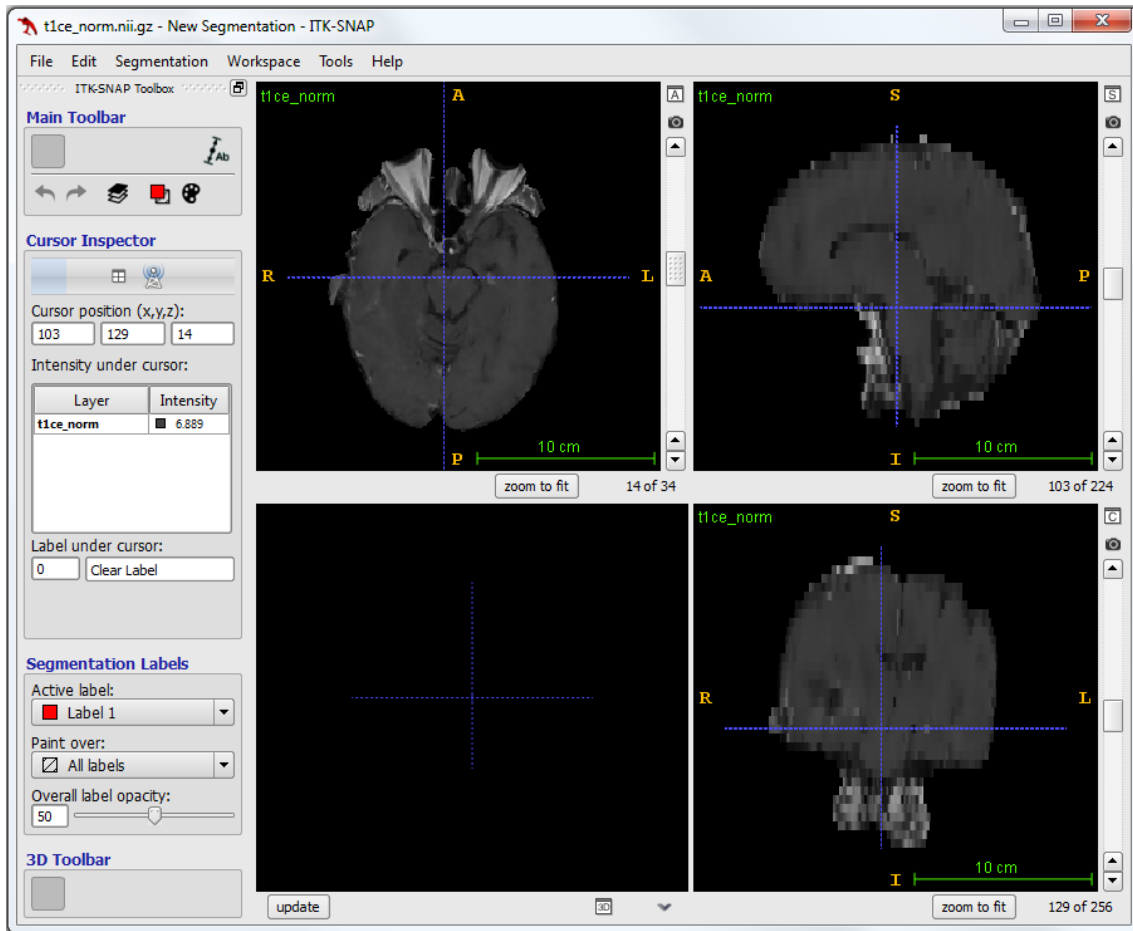
Precision Diagnosis, Risk Estimation:  Breast Density Factor	Predictive models:  Kaplan-Meier Estimator	Personalized Treatment:  Connectomics Infiltration	Radiogenomics Imaging signatures of molecular characteristics:  Breast MRI Phenotypes vs. Oncotype DX  Imaging Signatures of GBM mutations
--	---	--	--



Segmentation

- General purpose semi-automated segmentation: ITK-SNAP; Weighted geodesic segmentation
- Organ/Cancer-specific tools (GLISTR for brain gliomas; Breast cancer tools, fiber tract extraction for neurosurgical planning)

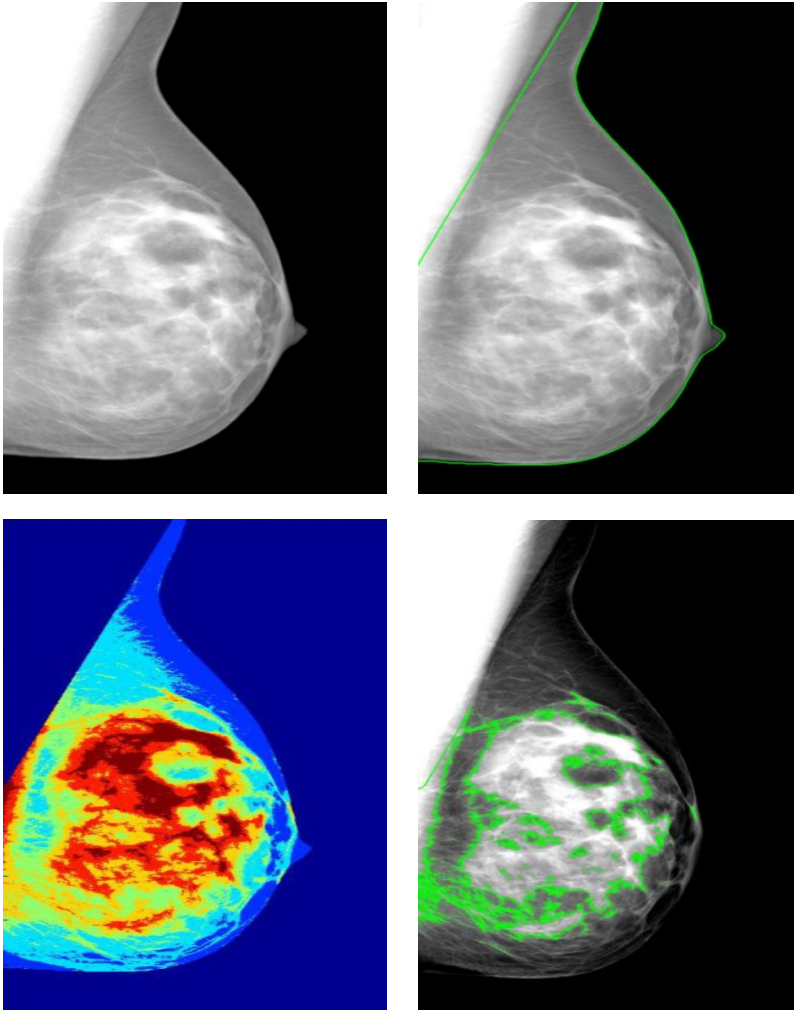
ITK-SNAP



Screenshot of ITK-SNAP's interface

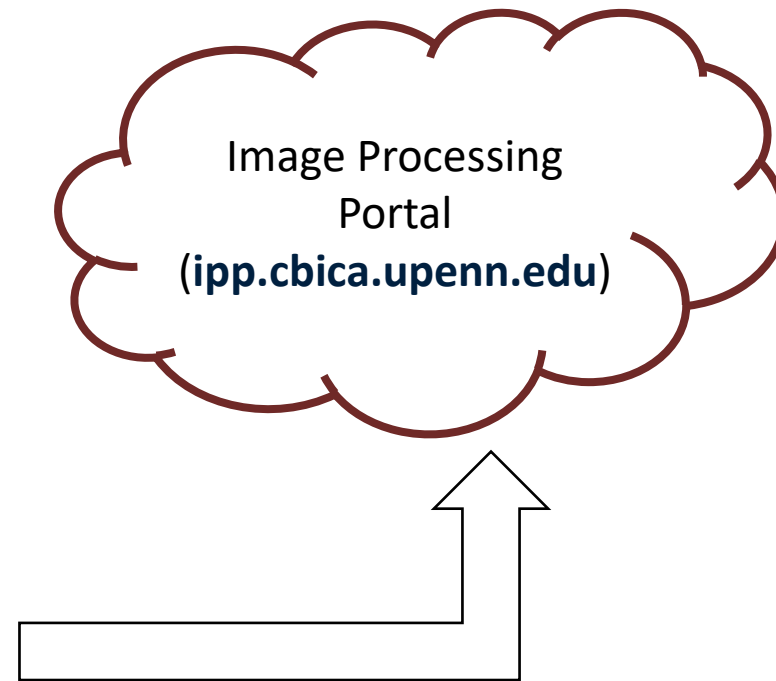
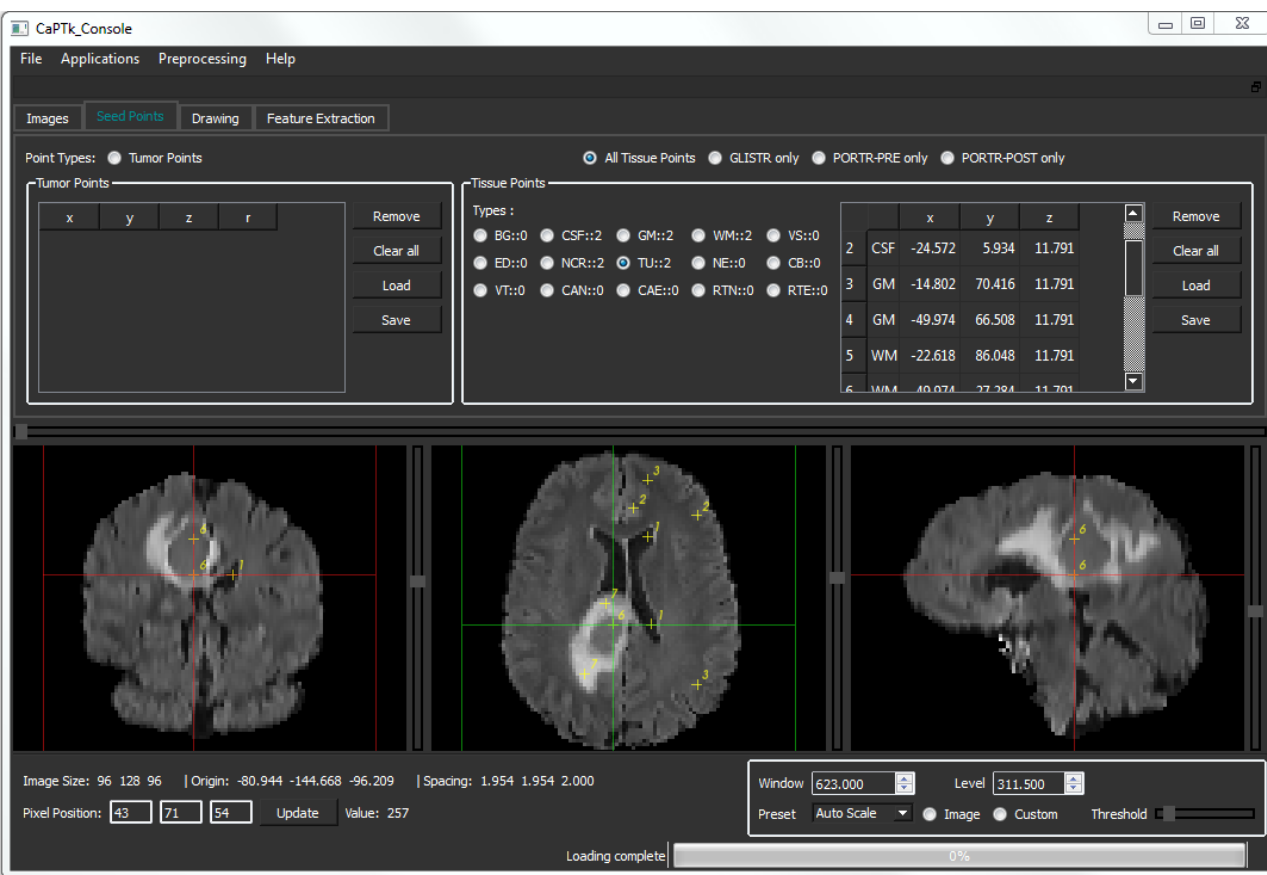
- Support for color, multi-channel, and time-variant images
- Segmentation done using Random Forest and Level Sets algorithms
- Transfer of data between ITK-SNAP and CaPTk is seamless – giving users the option to use the former's segmentation and user interaction functionality with latter's computation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

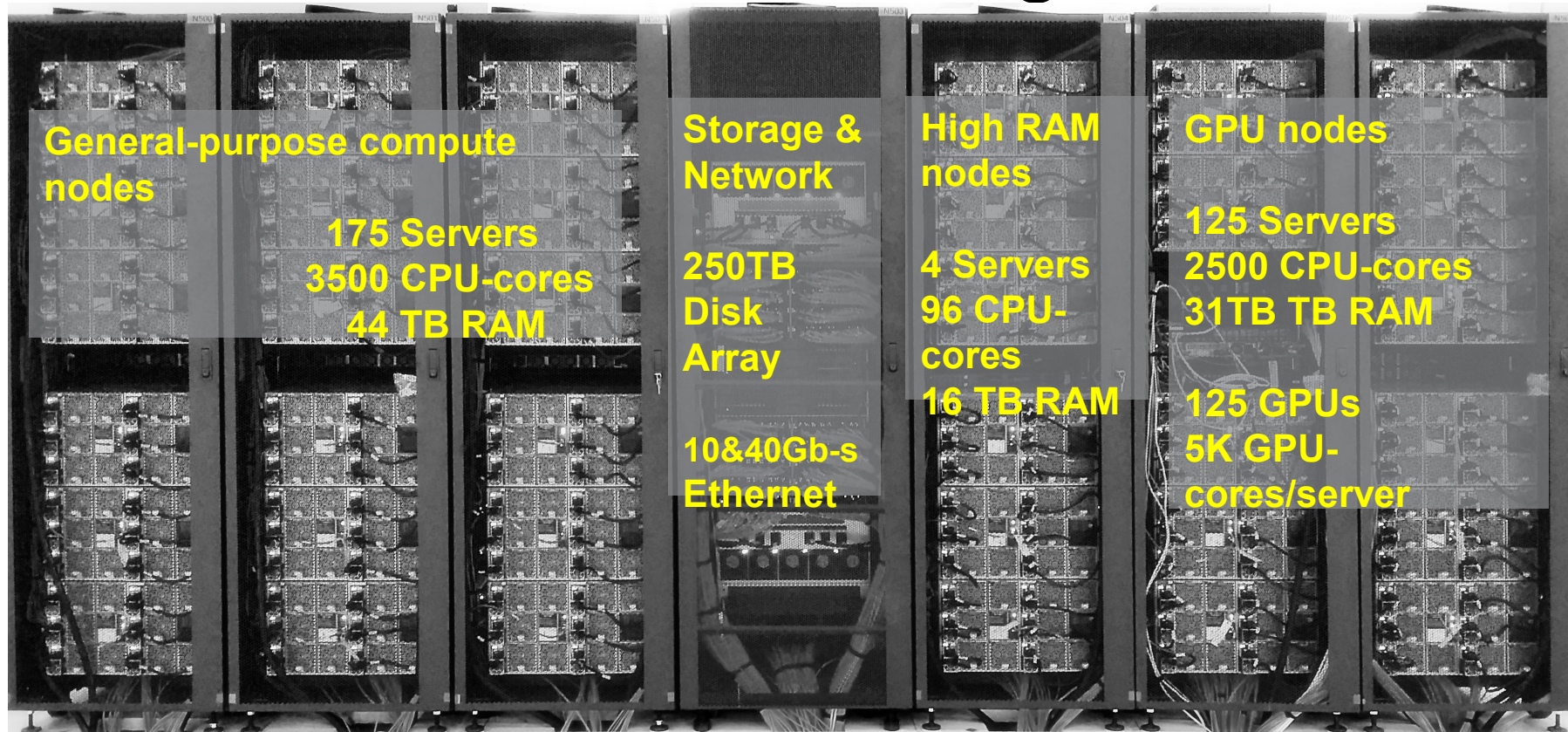


Generative
segmentation
↓
Discriminative
population
based
refinements
↓
Bayesian
personalized
refinements

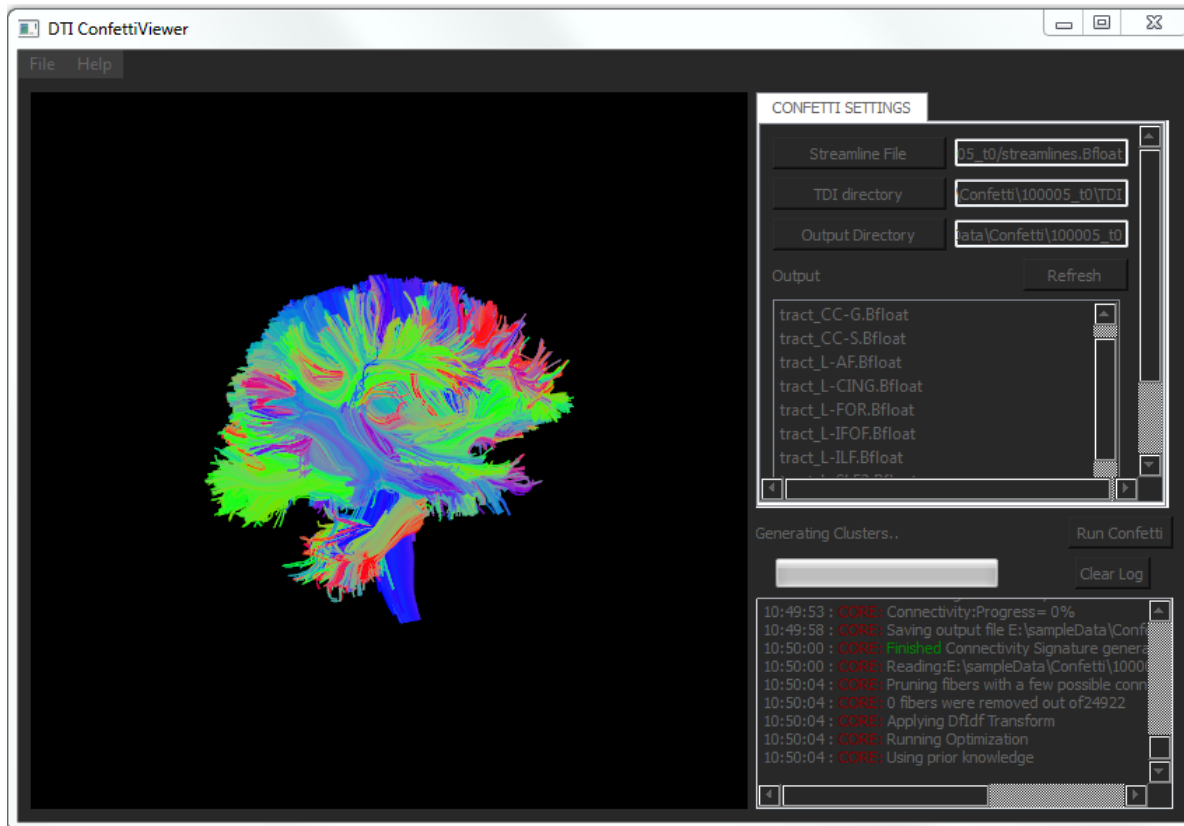
Initialize seed points for the MICCAI BRATS 2015 award-winning GLISTRboost method using CaPTk Console

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

Input Images

First Level

Image Analysis Algorithms

Segmentation:
Regions of Interest (ROIs)



Registration:
- Measure change with time:
A B B→A
- Population atlases:
Common vs. Rare

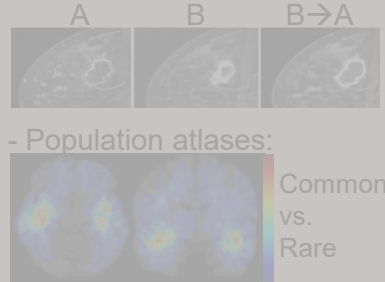


Image Harmonization:
Before After



Feature Extraction:
Texture, histogram, dynamics, spatial pattern



Image Operations:

- DICOM access
- Format conversion
- Intensity normalization
- Co-registration
- Noise Reduction
- ROI annotation
- Seed-point initialization

CaPTk Radiomic Panel

ITK

Feature Synthesis and Integration via Machine Learning

Open-CV

Second Level

Output Modules and Outcomes

Precision Diagnosis, Risk Estimation:



Breast Density Factor

Predictive models:

Kaplan-Meier Estimator

HR(low&high):10.64(95% CI 5.9-19.3, p<0.001)
HR(med&high):3.88(95% CI 2.3-6.6, p<0.001)
HR(low&med):2.77(95% CI 1.8-4.2, p<0.001)

Low SPI
Medium SPI
High SPI

Personalized Treatment:



Connectomics Infiltration

Radiogenomics
Imaging signatures of molecular characteristics:

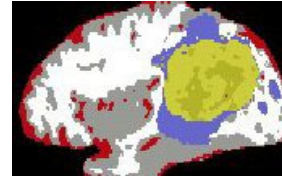


Breast MRI Phenotypes vs. Oncotype DX

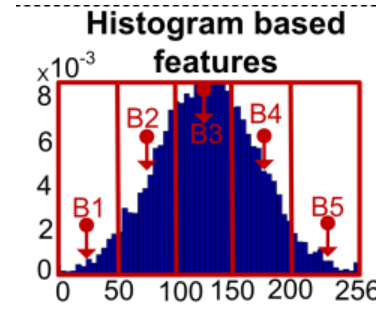
Imaging Signatures of GBM mutations

CapTk Radiomic Panel

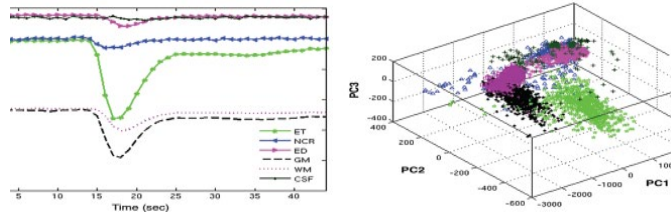
- Segmentations: volumes and signals within ROIs



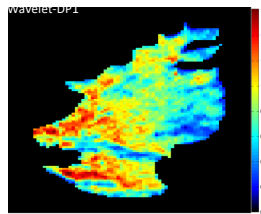
- Normalized histograms of different protocols; optimized binning



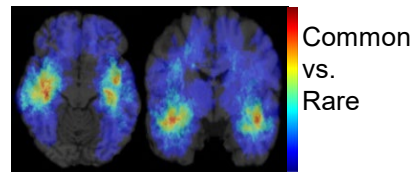
- Kinetics



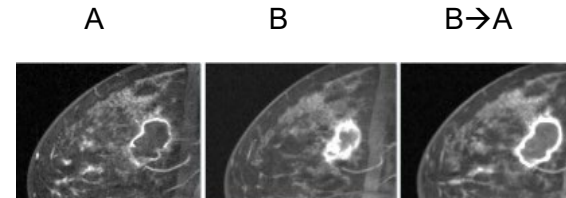
- Textures



- Spatial patterns/distributions



- Parametric maps from longitudinal scans

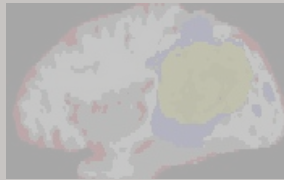


Input Images

First Level

Image Analysis Algorithms

Segmentation:
Regions of Interest (ROIs)



Registration:
- Measure change with time:
A B B→A
- Population atlases:
Common vs. Rare


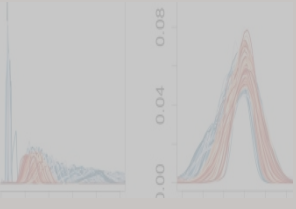


Image Harmonization:
Before After



Feature Extraction:
Texture, histogram, dynamics, spatial pattern

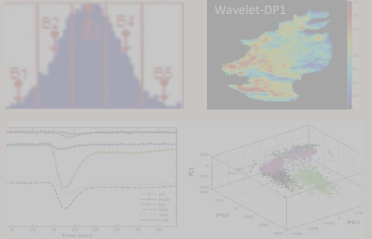


Image Operations:

- DICOM access
- Format conversion
- Intensity normalization
- Co-registration
- Noise Reduction
- ROI annotation
- Seed-point initialization

ITK

CaPTk Radiomic Panel

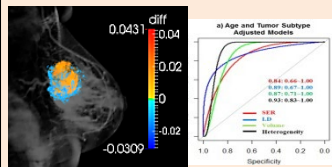
Feature Synthesis and Integration via Machine Learning

Open-CV

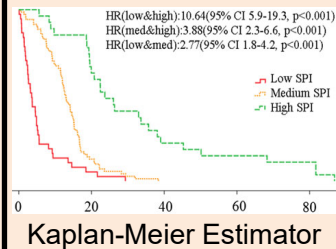
Second Level

Output Modules and Outcomes

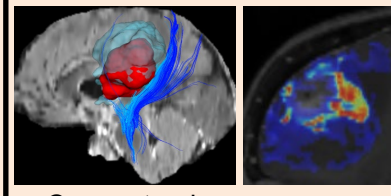
Precision Diagnosis, Risk Estimation:



Predictive models:

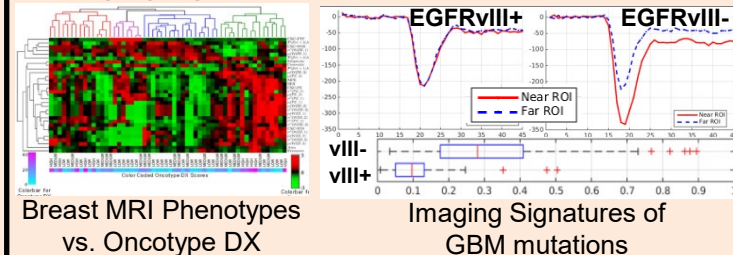


Personalized Treatment:



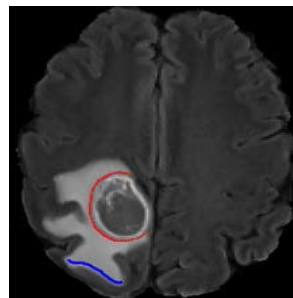
Radiogenomics

Imaging signatures of molecular characteristics:

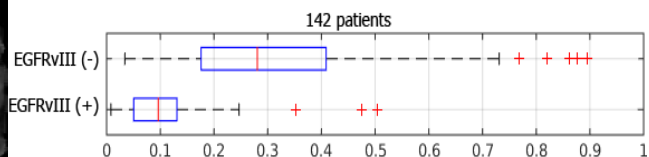


Computational Neuro-Oncology

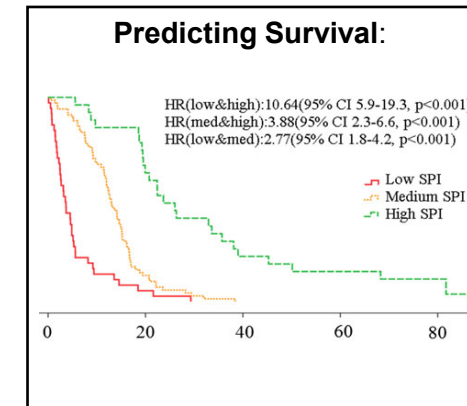
Imaging Signatures of Molecular Characteristics



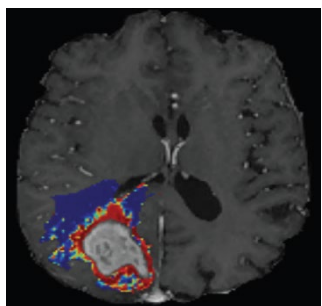
Bakas et al, Clinical Cancer Research 2017



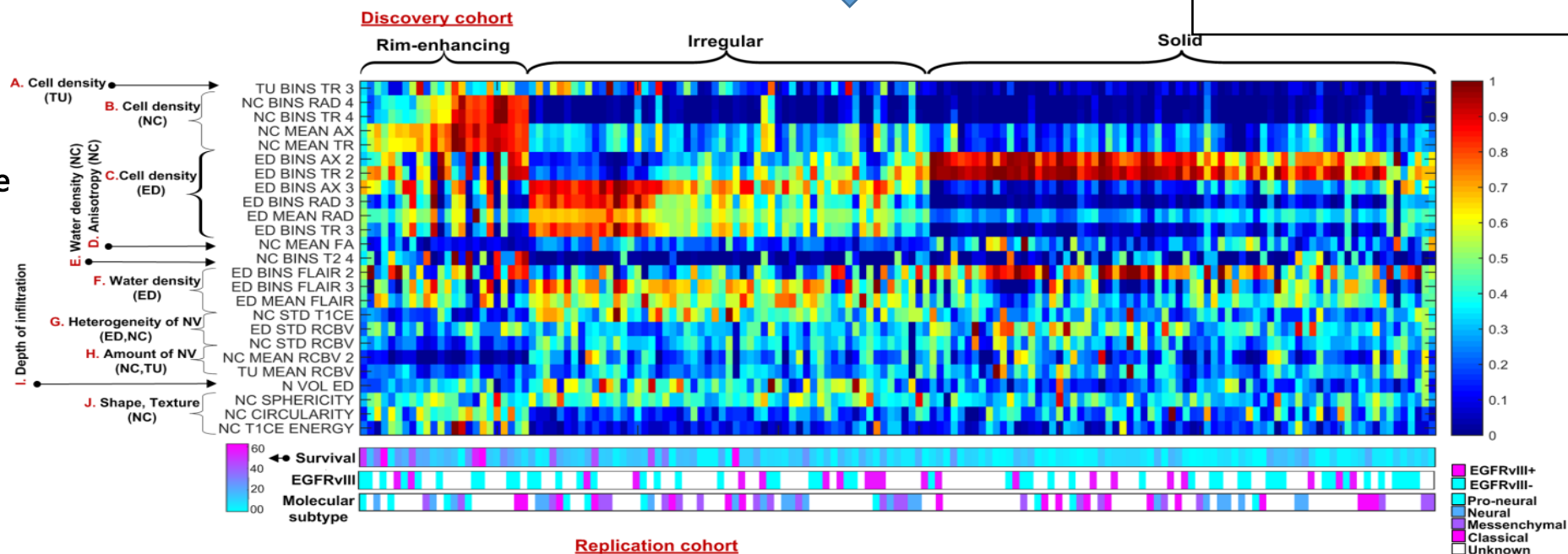
Subtyping using Clustering of the CaPTk Radiomic Panel



Predicting Infiltration and Recurrence

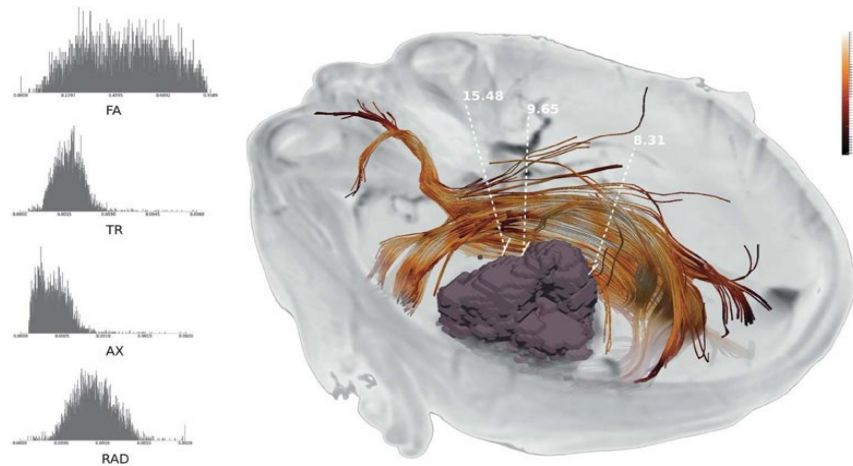


Akbari et al., Radiology, 2014
Akbari et al., Neurosurgery, 2016

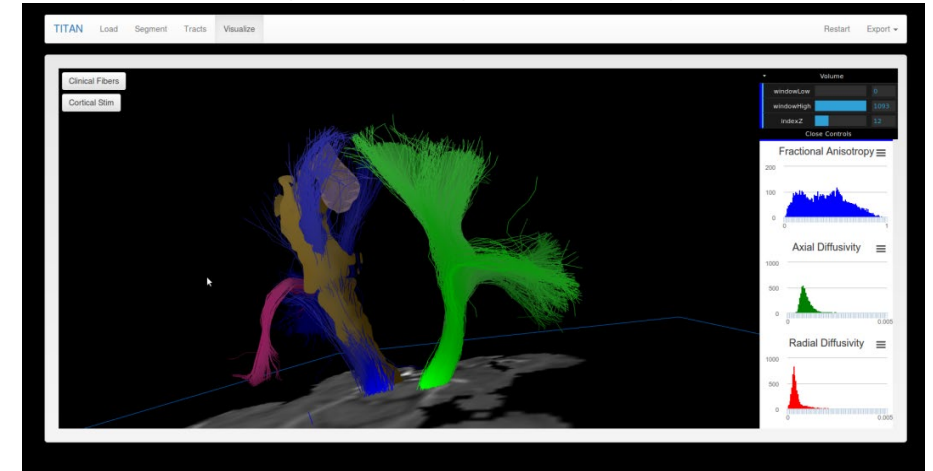


Computational study of Brain Connectivity

Peri-lesional Effects of GBMs

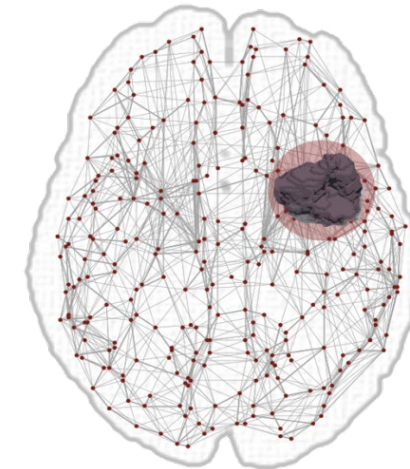


Web-based Integrated Surgical Planning Environment

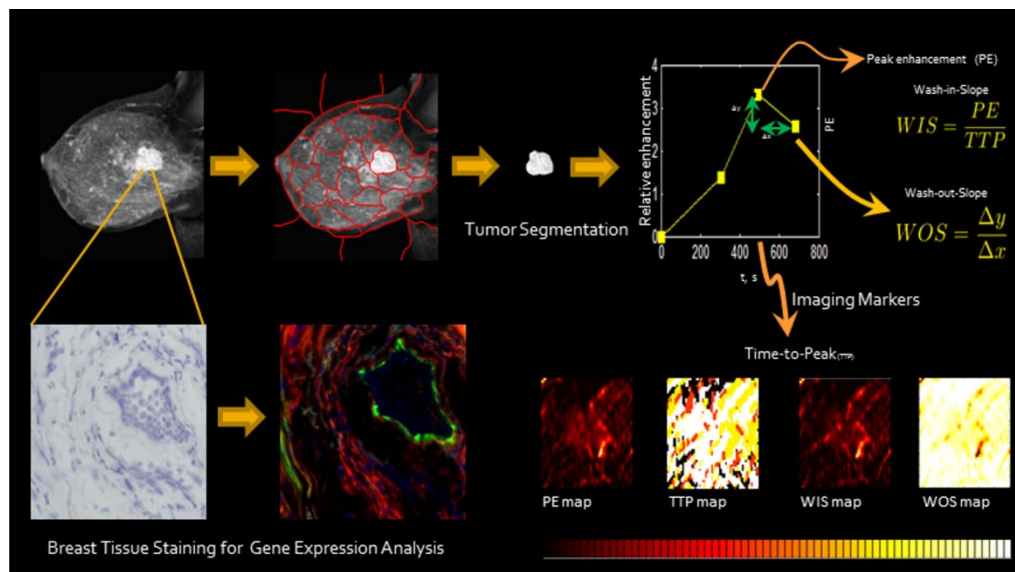


- Automated atlas-based tract extraction (using connectivity signatures instead of shape help address mass effect)
- Edema invariant tractography (using multicompartment models fitted to multishell imaging)
- Tumor connectome (effect of tumor on distant regions, regional vulnerability and functional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

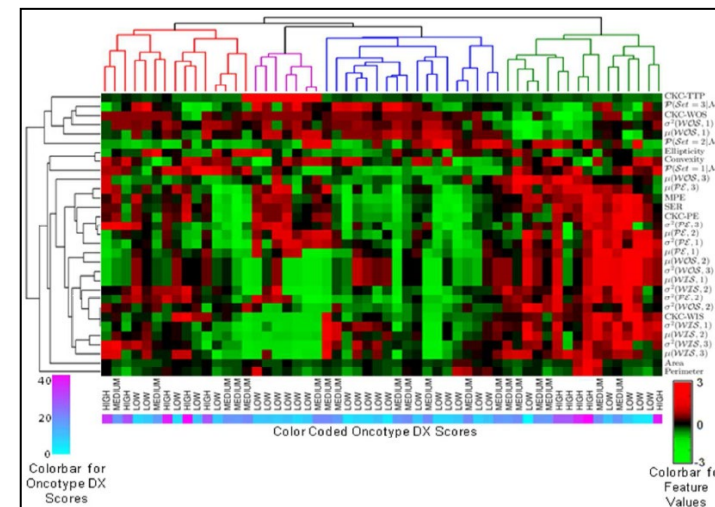
Global Effects of GBMs



Radiomic Breast Cancer Phenotypes



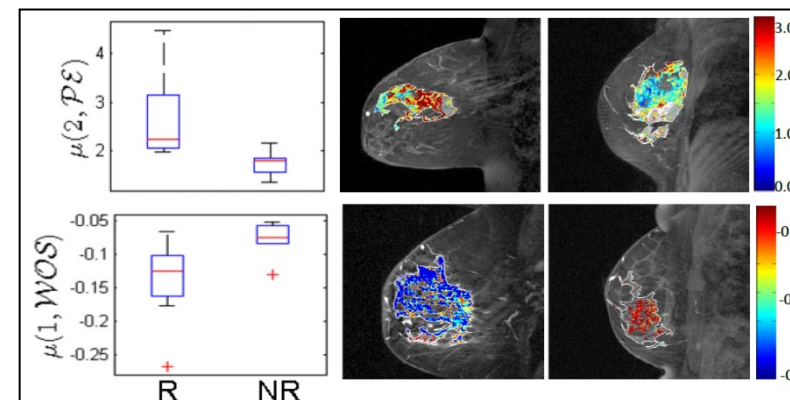
Ashraf et al., IEEE TMI 2013; Mahrooqhy et al. IEEE TBME 2015



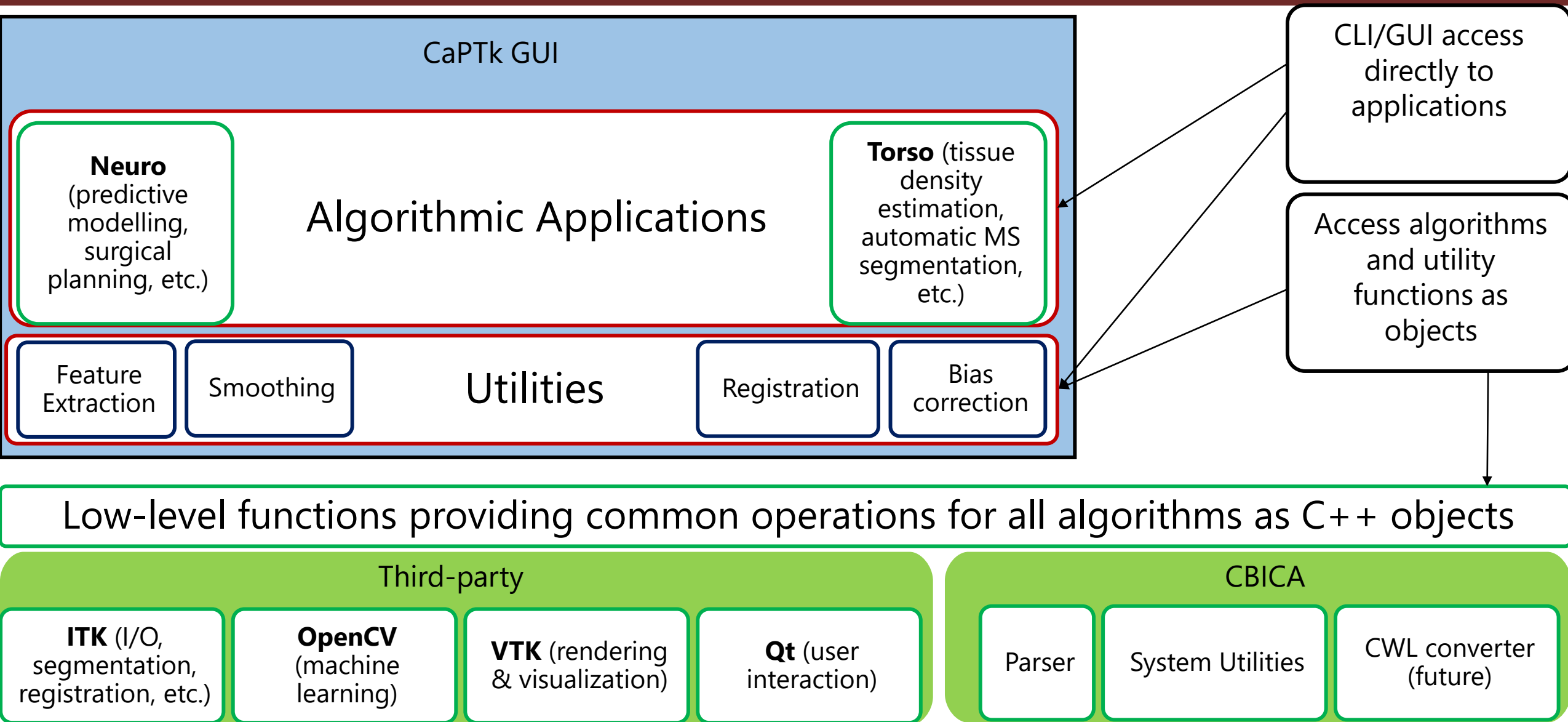
Intrinsic Imaging Phenotypes for Breast Cancer Prognostic and Predictive Value

Breast Cancer Phenotyping via Imaging:

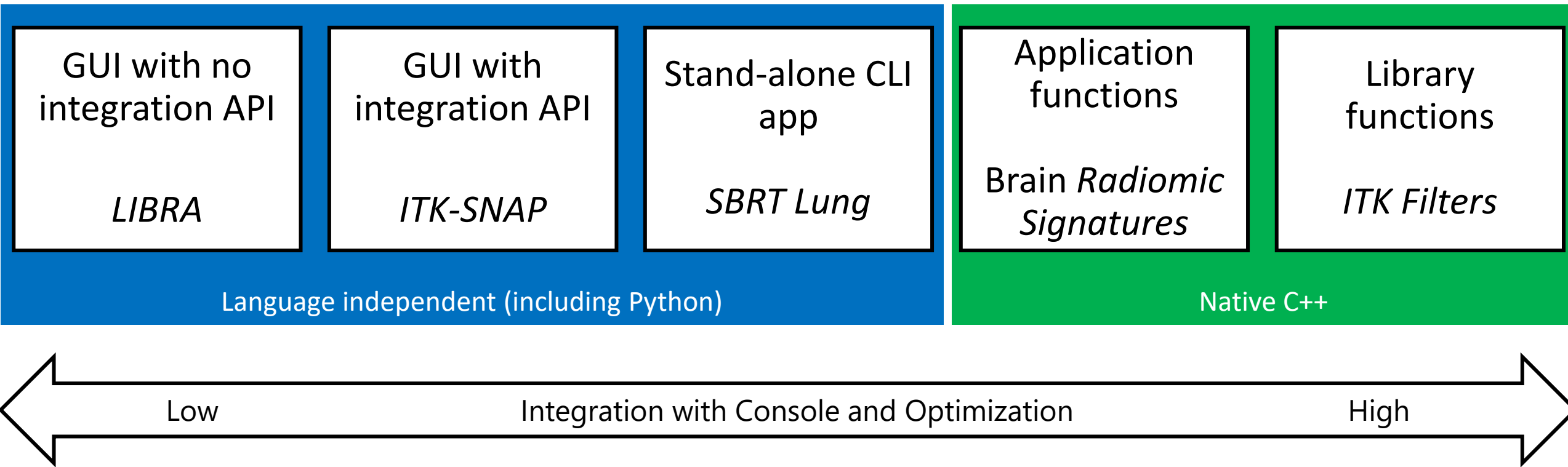
- Segmentation and multi-parametric feature extraction
- Identification of intrinsic phenotype patterns
- Prognostication and treatment response prediction



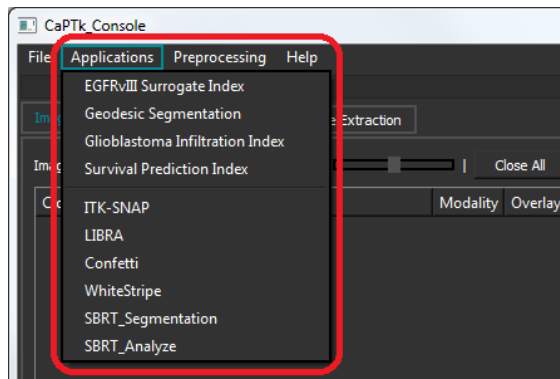
Software Architecture Overview



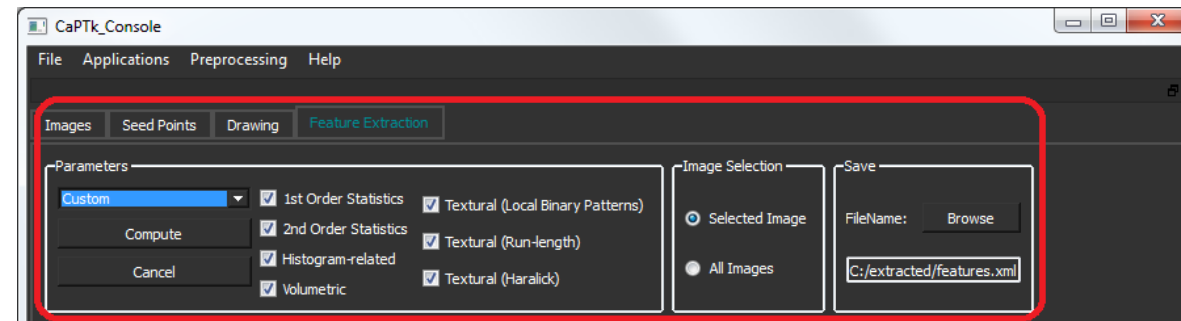
Application Integration Levels



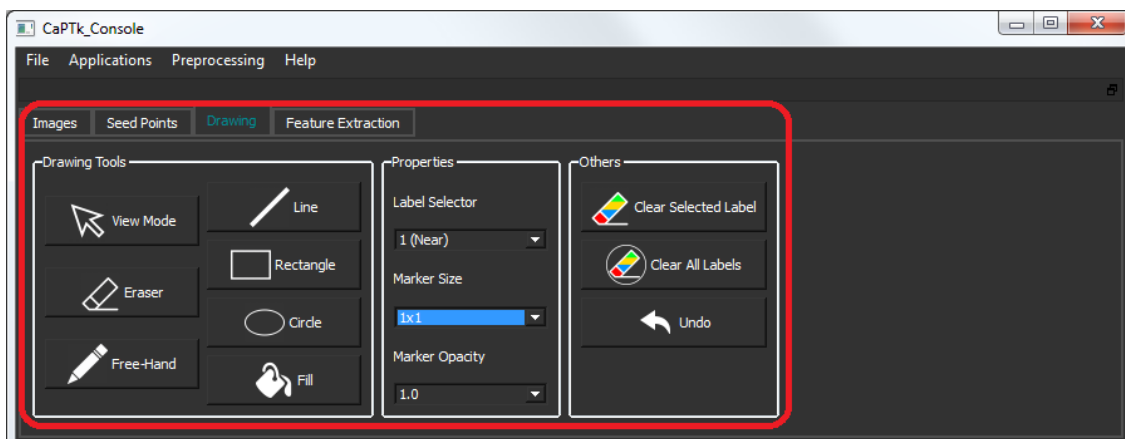
User Interface Screenshots



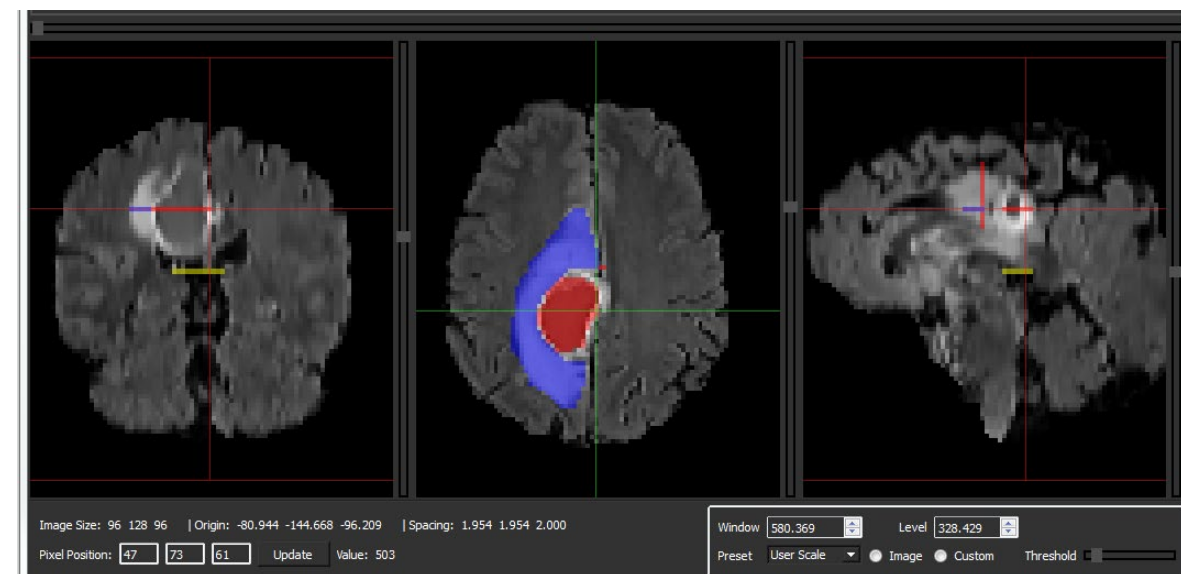
All available Applications



Feature Panel



Drawing annotations



Visualization Pane

EGFR Radiogenomic Signature Example Screenshot

Loaded Images and modalities

The screenshot displays the CaPTk_Console software interface. At the top, there is a menu bar with 'File', 'Applications', 'Preprocessing', and 'Help'. Below the menu bar, there are tabs for 'Images', 'Seed Points', 'Drawing', and 'Feature Extraction'. The 'Images' tab is active, showing a table of loaded images:

Close	Type	Name	Modality	Overlay
1	X	IMAGE Flair_pp.nii.gz	FLAIR	
2	X	IMAGE Perf_pp.nii.gz	PERF	
3	X	IMAGE T1CE_pp.nii.gz	T1Gd	

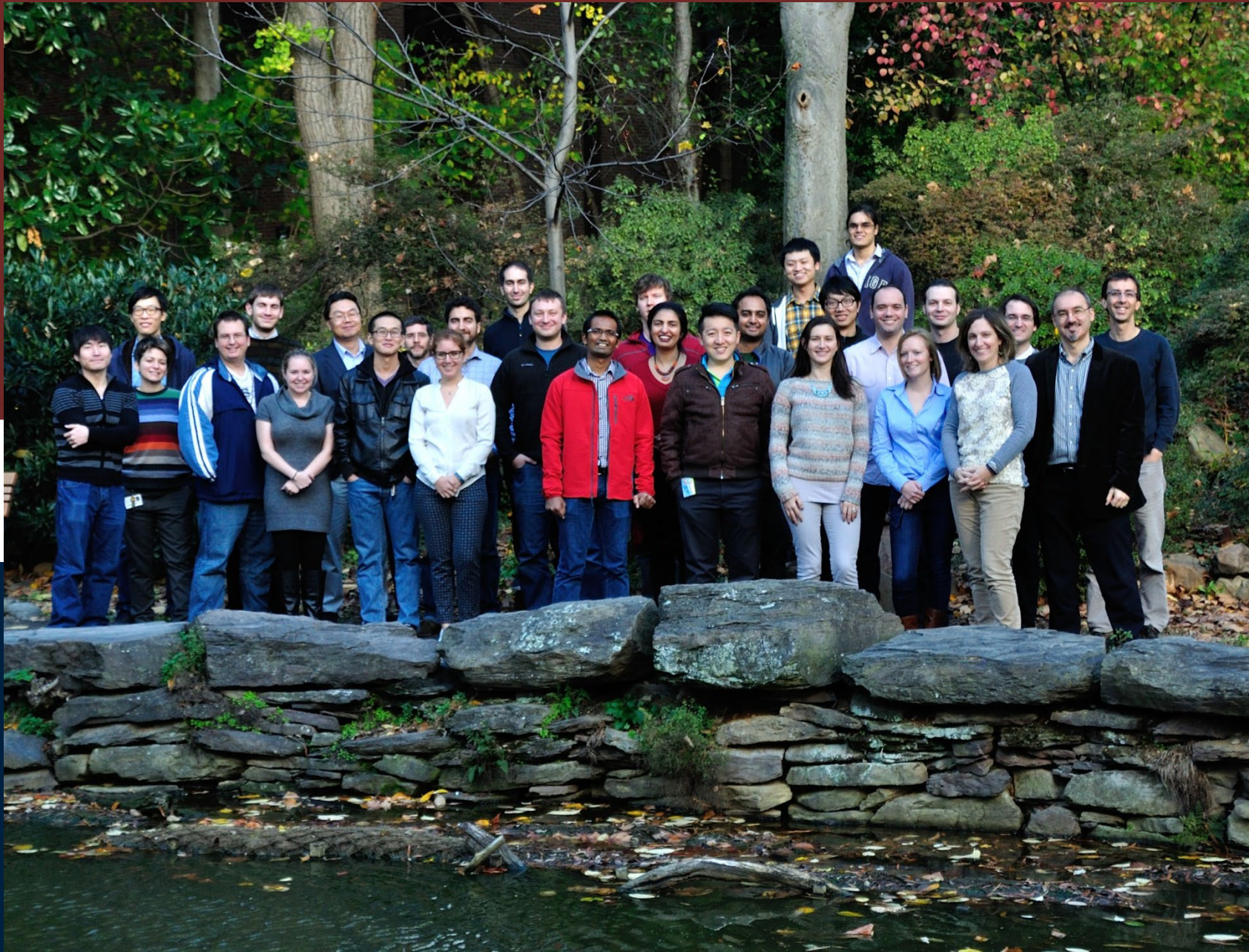
An 'Output Results' pop-up box is overlaid on the image list, containing the following information:

- PHI = 0.0714689
- (Near:Far) Peak Height ratio = 2.14412
- Near ROI voxels used = 48/48
- Far ROI voxels used = 47/47
- PHI Threshold = 0.1377 [based on 142 UPenn brain tumor scans]

At the bottom of the interface, there are three image viewers showing different views of the brain scan. Below the viewers, there are controls for 'Image Size', 'Origin', 'Spacing', 'Pixel Position', 'Window', 'Level', 'Preset', and 'Threshold'.

Pop-up box showing results

Various image properties



User Workflow

