The Cancer Phenomics Toolkit (CaPTk)



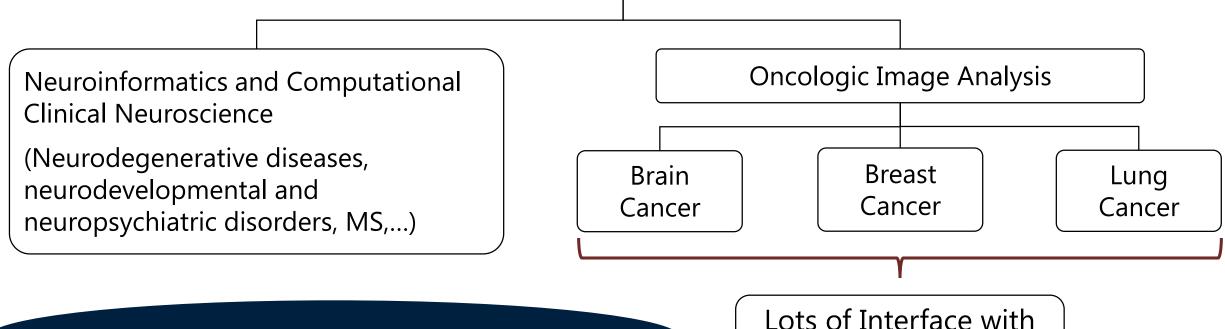
Christos Davatzikos Ragini Verma Yong Fan Despina Kontos Paul Yushkevich Taki Shinohara Sarthak Pati Mark Bergman

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







"If you cannot measure it, then it is not science"

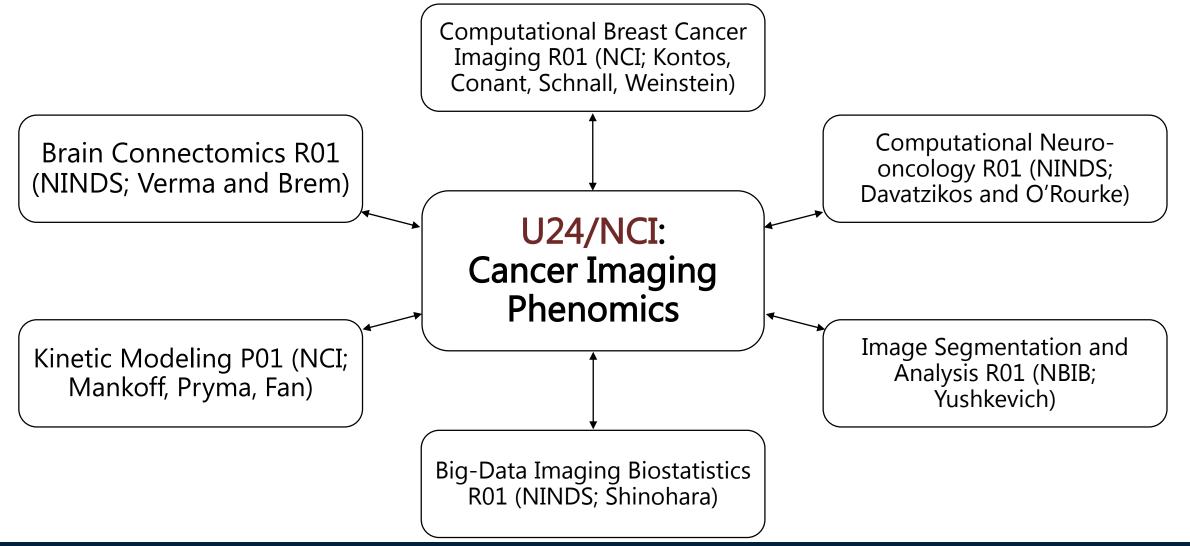
From lecture to the Institution of Civil Engineers, London (3 May 1883)

Lord Kelvin, 1824-1907



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Oncologic Imaging Analytics





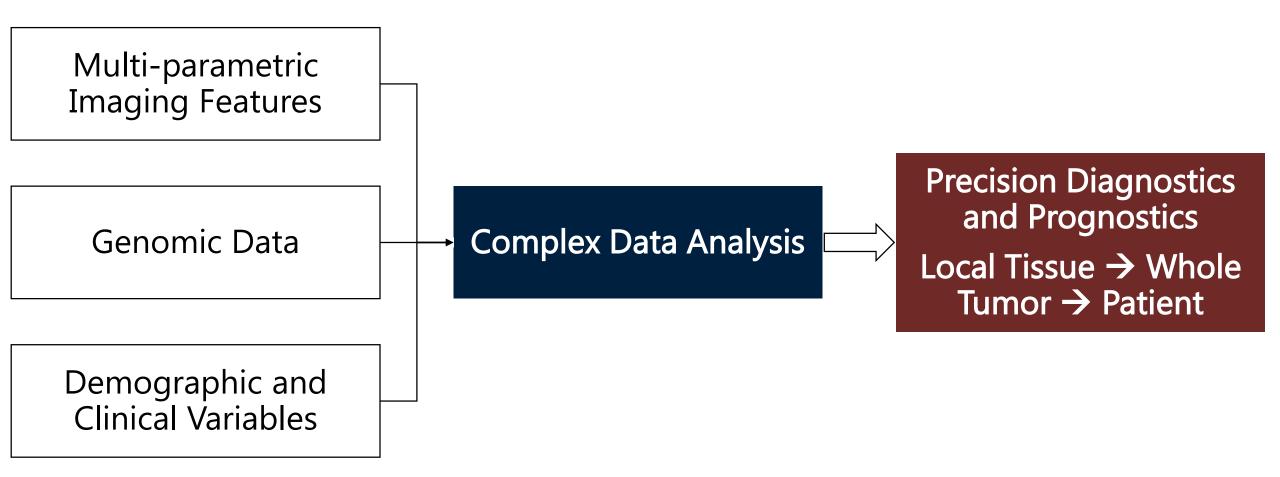
Two Major Foci of CapTk Program

• To leverage a rich family of <u>advanced image computing algorithms</u>

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



U24/ NCI: Cancer Imaging Phenomics





Main Elements of CaPTk

Image Analysis Algorithms: Extraction of rich set of multi-parametric imaging features; image segmentation and co-registration

<u>Precision Diagnostics Using Machine</u> <u>Learning</u>: Risk for cancer development, risk for recurrence, prediction of survival, imaging genomics

Personalized Treatment Planning: Guide tumor resection and targeted radiation, estimate functional loss based on connectomic features...

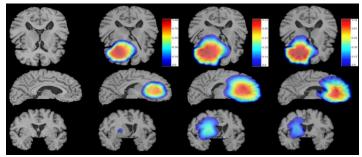
1. Neurosurgical planning workstation: from precision diagnostics to personalized treatment

2. Precision diagnostics workstation of breast cancer



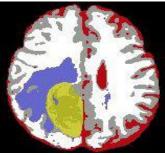
Computational Neuro-Oncology

Modeling tumor growth



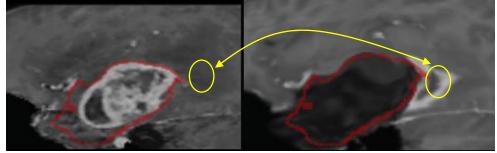
Hogea et al., J. Math. Biol., 2008

Segmentation



Gooya et al., TMI, 2012 Bakas et al., MICCAI BRATS 2015 **1**st prize

Pre-operative to Post-Recurrence Registration

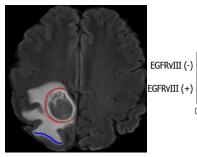


Kwon et al., TMI, 2014

Imaging Signatures of Molecular Characteristics

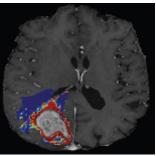
142 patients

0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9



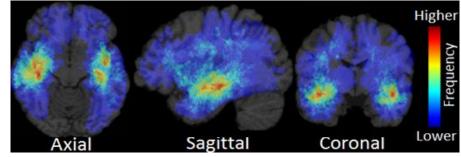
Bakas et al., SNO 2015

Predicting Recurrence



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

Spatial Distribution Atlases

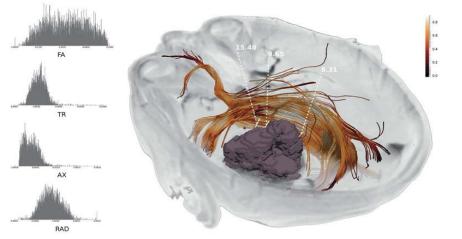


Bilello et al., NeuroImage: 2016



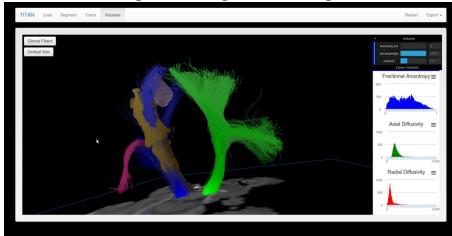
Computational study of Brain Connectivity

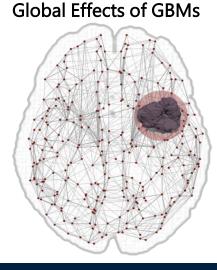
Peri-lesional Effects of GBMs



- 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)

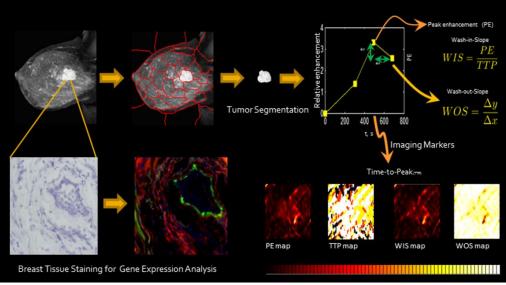
Web-based Integrated Surgical Planning Environment





Pennet

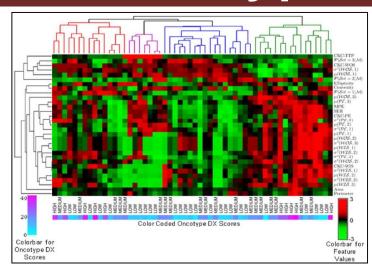
Radiomic Breast Cancer Phenotypes



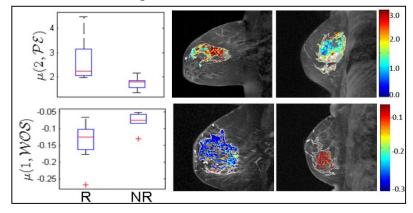
Ashraf et al., IEEE TMI 2013; Mahrooghy et al. IEEE TBME 2015

Breast Cancer Phenotyping via Imaging:

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



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





Goals

• Enable the larger scientific community (radiologists, clinicians, neuro-scientists and other researchers who don't deal with command line interfaces) to use cutting edge algorithms from computational research centers for clinically relevant studies through a user-friendly, platform-independent interface.

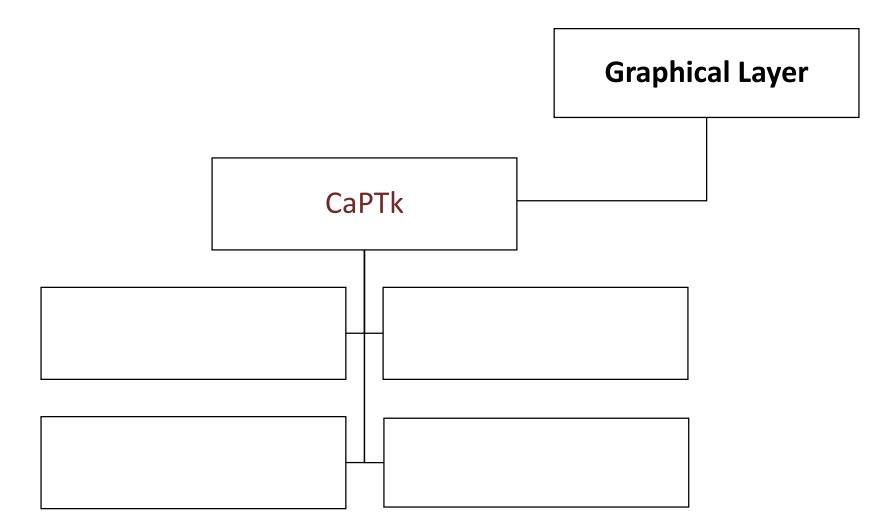


Goals

- Enable the larger scientific community (radiologists, clinicians, neuro-scientists and other researchers who don't deal with command line interfaces) to use cutting edge algorithms from computational research centers for clinically relevant studies through a user-friendly, platform-independent interface.
- Provide a platform for researchers from computational centers to incorporate their algorithms in a form which can be used to target the larger scientific community as quickly as possible.

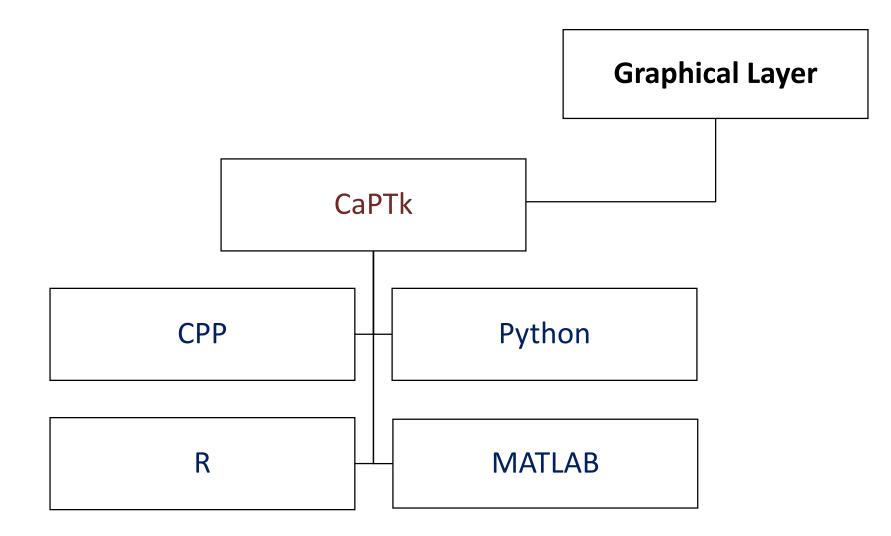


Overview of Architecture



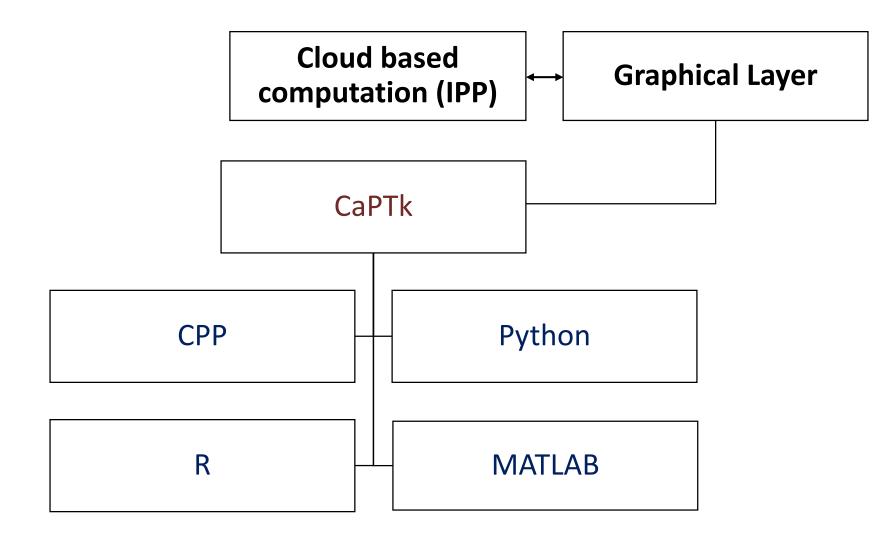


Overview of Architecture





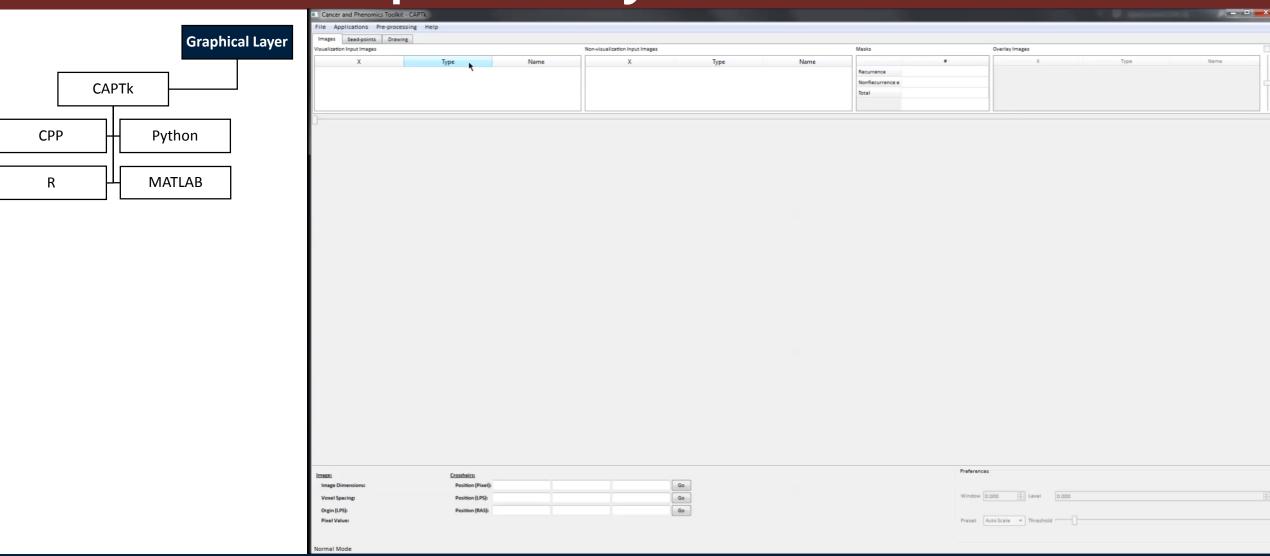
Overview of Architecture





ipp.cbica.upenn.edu

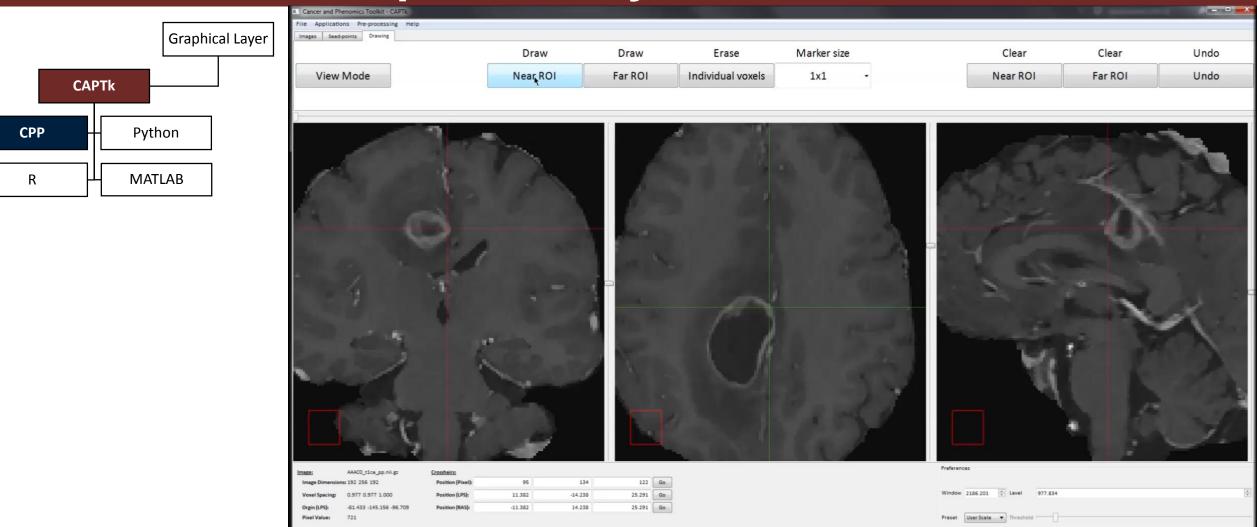
Graphical Layer & GLISTR



Penny of Pennyuvana

GLISTRboost: Combining Multimodal MRI Segmentation, Registration, and Biophysical Tumor Growth Modeling with Gradient Boosting Machines for Glioma Segmentation – Bakas et al. [BRATS Winner 2015]

Graphical Layer & EGFR





Identification of Imaging Signatures of the Epidermal Growth Factor Receptor Variant III (EGFRvIII) in Glioblastoma – Bakas et al.

EGFR Results

0

0.1

0.2

0.3

142 patients

0.5

0.6

0.7

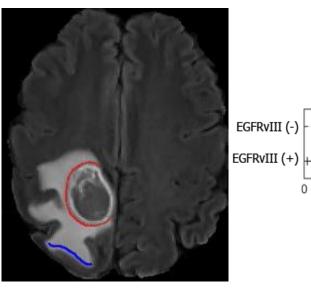
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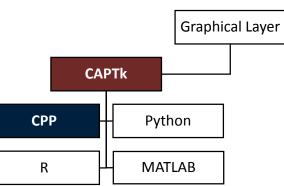
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Bakas et al., SNO 2015



Geodesic Segmentation using CaPTk



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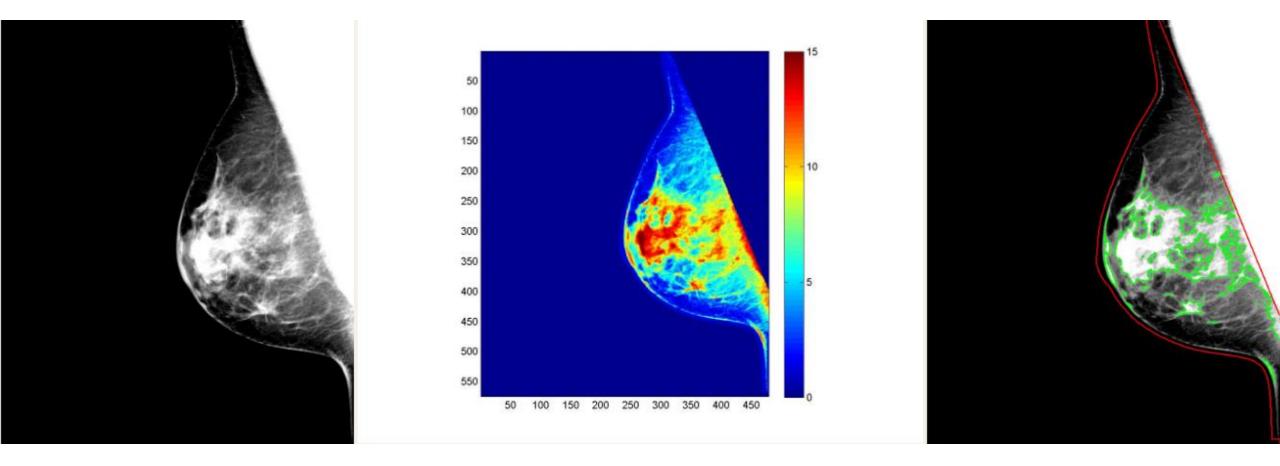
Adaptive Geodesic Transform for Segmentation of Vertebrae on CT images – Gaonkar et al.

TITAN – Edema Invariant Tractography

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LIBRA: Fully-automated Breast Density Estimation

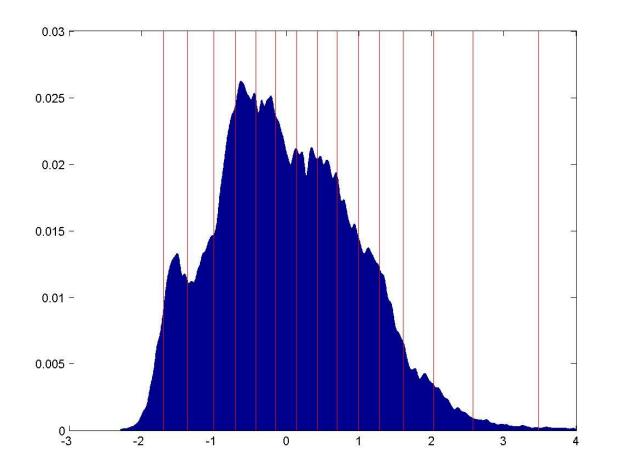


The breast density maps using an adaptive multi-class fuzzy c-means segmentation with SVM classification



Estimation of breast percent density using full field digital mammography images via adaptive fuzzy cmeans clustering and SVM segmentation – Keller et al.

LIBRA: Adaptive Histogram-based Clustering



The breast region gray-level intensity histogram (z-scored) and FCM-cluster centers



Estimation of breast percent density using full field digital mammography images via adaptive fuzzy cmeans clustering and SVM segmentation – Keller et al.

LIBRA being called from CAPTk

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Estimation of breast percent density using full field digital mammography images via adaptive fuzzy cmeans clustering and SVM segmentation – Keller et al.







Section of Biomedical Image Analysis