Center for Computational Imaging and Personalized Diagnostics (CCIPD)

2012 Annual Report

Director: Dr. Anant Madabhushi
Associate Professor,
Department of Biomedical Engineering
LCIB-CCIPD Transition

- We have moved! LCIB is now the Center of Computational Imaging and Personalized Diagnostics (CCIPD) within the Department of Biomedical Engineering at Case Western Reserve University.

- Dr. Madabhushi and 12 members relocated to start CCIPD at CWRU.
CCIPD in 2012
525 Wickenden Building
Dept. of Biomedical Engineering
Case Western Reserve University
2071 Martin Luther King Drive
Cleveland, Ohio 44106-7207

Faculty Offices  Center Space  Center Entrance
Center Members

Group dinner in Cleveland, Sept. 2012

Farewell dinner in NJ, August 2012
CCIPD Members

Center Director: Dr. Anant Madabhushi

Research Faculty
- Satish Viswanath, PhD
- Pallavi Tiwari, PhD

Research Associates
- Mirabela Rusu, PhD
- Tao Wan, PhD
- Haibo Wang, PhD

Undergraduate Students
- Eileen Huang*
- Sudha Karthigeyan*
- Aparna Kannan*
- Srivathsan Prabhu*
- Gabriel Ewing

Graduate Students
- Julian Modesto *
- Michael Yim*
- Andrew Janowczyk (IIT, Bombay)
- Rachel Sparks (Rutgers, NJ)
- Ajay Basavanhally (Rutgers, NJ)
- George Lee (Rutgers, NJ)
- Rob Toth (Rutgers, NJ)
- Shoshana Ginsburg
- Sahir Ali
- Asha Singanamalli

* At Rutgers University
Center Members

Research Faculty

Pallavi Tiwari, PhD
Satish Viswanath, PhD

Research Associates

Mirabela Rusu, PhD
Tao Wan, PhD
Haibo Wang, PhD

Center Director
Dr. Anant Madabhushi, PhD
Center Members

Graduate Students

Sahir Ali
Ajay Basavanhally
Andrew Janowczyk
George Lee
Shoshana Ginsburg

Rachel Sparks
Rob Toth
Asha Singamanelli
Recent Alumni

**Research Faculty**

James Monaco, PhD  
Research Scientist at VuCOMP

**PostDocs**

Jun Xu, PhD  
Professor at Nanjing University

Gaoyu Xiao, PhD

**PhD Students**

Pallavi Tiwari, PhD  
Graduated from LCIB in May, 2012  
Research Faculty at Case Western Reserve University

Satish Viswanath, PhD  
Graduated from LCIB in May, 2012  
Research Faculty at Case Western Reserve University

Shannon Agner  
4th year medical student at UMDNJ-RWJMS
Recent Alumni

**PhD Students**

Jon Chappelow, PhD Research Scientist at Accuray Inc.

Scott Doyle, PhD Research Scientist at Ibris Inc.

**Master Students**

Akshay Shridar Assistant Project Manager at Integra Life Sciences

Najeeb Chowdhury Healthcare Market Research Analyst at AlphaDetail Inc.

**Assistant**

Rhonda Breen-Simone Administrative Assistant at Dept. of Nutritional Sciences, Rutgers University
Recent Alumni

Undergraduate Students

Joe Galero
Graduate Student
at Johns Hopkins University

Pratik Patel
Intern at BioLite

Abhishek Golugula
Employee at Accenture

Elaine Yu
Graduate Student
at UC Berkeley
Acknowledging just some of our outstanding clinical collaborators

CCIPD also acknowledges the larger number of excellent clinical collaborators across CINJ, Rutgers, Case Western, MD Anderson, UT Southwestern Dallas, UCSF, UPENN, SUNY Buffalo, NYU we have been privileged to work with.
Student Accomplishments

Pallavi Tiwari and Satish Viswanath at the 2012 Graduate Reception having obtained their PhDs, May 2012.

Group photo with Pallavi Tiwari & Satish Viswanath immediately after their successful PhD thesis defense, April 2012.
Conference Participation 2012

SPIE 2012 Best Poster (Cum Laude) in CAD: Rachel Sparks

Conference Participation 2012

VLPR: Rob Toth (left) Sahir Ali (right)

VLPR: Sahir Ali, Rob Toth, Anant Madabhushi, Jun Xu (alum) with Dr. Xu’s graduate students (standing)
Dr Madabhushi attended and presented at the Radio-omics Workshop organized by Dr. Bob Gillies at the Moffit Cancer Center in Tampa, FL. Also attendance were folks from the Cancer Imaging Program at NCI (Drs Larry Clarke and Nordstrom) and members of the Quantitative Imaging Network (QIN).
CCIPD Workshop 2012

The HIMA (Histopathology Image Analysis) workshop – 4th year running of HIMA at MICCAI 2012
MICCAI Grand Challenge: 
**Prostate MR Image Segmentation 2012**

October 1, 2012
Nice, France

Welcome to the website of the ‘Prostate MR Image Segmentation’-challenge 2012. The goal of this challenge is to compare interactive and (semi)-automatic segmentation algorithms for MRI of the prostate. During MICCAI2012 the results of the challenge will be presented in conjuction with a live challenge, evaluating the algorithms on unseen data.

**Update November 10th 2012:** The results for the MICCAI2012 challenge are now online and the challenge is open for new submissions again.

**Organizers**

**MICCAI Workshop Organizers**
Dean Barrat, University College London, London, England
Jason Dowling, CSIRO Australian e-Health Research Centre, Herston, Australia
Henkjan Huisman, Radboud University Nijmegen Medical Centre, Nijmegen, The Netherlands
Anant Madabhushi, Rutgers University, New Jersey, USA

**Challenge Organizers**
Bram van Ginneken, Radboud University Nijmegen Medical Centre, Nijmegen, The Netherlands
Sjoerd Kerkerstra, Radboud University Nijmegen Medical Centre, Nijmegen, The Netherlands
Geert Litjens, Radboud University Nijmegen Medical Centre, Nijmegen, The Netherlands
Rob Toth, Rutgers University, New Jersey, USA

**Program Committee**
Aaron Fenster (Robarts Institute)
Imam Samir Yebk (Illinois Institute of Technology)
Olivier Salvado (CSIRO)
Dinggang Shen (UNC Chapel Hill)
Pingkun Yan (Xi’an Institute of Optics and Precision Mechanics, Chinese Academy of Sciences)
Parag Abolinsammi (University of British Columbia)
David Hawkes (University College London)
Sebastian Ourselin (University College London)
Robert Toth (Rutgers University)
Nasr Makni (EOS Imaging)
Nobi Hato (Harvard Medical School)
Stefan Klein (Erasmus Medical Center Rotterdam)

The prostate imaging challenge workshop- first prostate segmentation challenge at MICCAI attended by 13 participating teams.
Summary of Accomplishments 2012

- Lab Members: 20
  - Faculty: 3
  - Research Associates: 3
  - Graduate Students: 8
  - Undergraduate Students: 7

- Theses (3): 2 PhD + 1 MS
- Books: 1
- Journal Papers: 19
- Peer-Reviewed Conference Papers: 19
- Peer reviewed Abstracts: 7

- Issued Patents: 3
- Grants: 4
- Ongoing Projects: 31
Peer Reviewed Publications for 2012

Summary

<table>
<thead>
<tr>
<th>Type</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theses</td>
<td>2</td>
</tr>
<tr>
<td>Journal Papers</td>
<td>18</td>
</tr>
<tr>
<td>Conference Papers</td>
<td>18</td>
</tr>
<tr>
<td>Abstracts</td>
<td>6</td>
</tr>
</tbody>
</table>
Books


Peer Reviewed Publications

Journal Papers

- Toth, R, Gentile, J, Sperling, D, Madabhushi, A, “Simultaneous Segmentation of Prostatic Zones Using Active Appearance Models with Multiple Coupled Levelsets”, Computer Vision and Image Understanding, Minor changes.
- Janowczyk, A, Chandran, S, Madabhushi, A, “Quantifying local heterogeneity via morphologic scale: Distinguishing tumoral regions from stromal regions”, Journal of Pathology Informatics, Accepted.
- Tiwari, P, Kurhanewicz, J, Madabhushi, A, “Multi-Kernel Graph Embedding for Detection, Gleason Grading of Prostate Cancer via MRI/MRS”, Medical Image Analysis, Accepted.
Peer Reviewed Publications

Journal Papers (Contd.)

Peer Reviewed Publications

Journal Papers (Contd.)

Peer Reviewed Publications

Peer-reviewed Conference Papers

Peer Reviewed Publications

Peer-reviewed Conference Papers (Contd.)

Peer Reviewed Publications

Peer-reviewed Conference Papers (Contd.)

- Gleason grading of prostate histology utilizing statistical shape model of manifolds (SSMM), Sparks, R, Madabhushi, A, SPIE Medical Imaging, 2012, Accepted (Cum Laude, Best Poster in CAD Conference at SPIE Medical Imaging 2012).
Peer Reviewed Abstracts

Patents

Issued Patents

- “Systems and Methods for Classification of Biological Datasets”, Anant Madabhushi, Michael D. Feldman, Jianbo Shi, Mark Rosen, John Tomaszewski, United States Serial Number (USSN): 8,204,315.
- “Malignancy Diagnosis Using Content-Based Image Retrieval of Tissue Histopathology”, Anant Madabhushi, Michael D. Feldman, John Tomaszewski, Scott Doyle, United States Serial Number (USSN): 8,280,132.

Patents Pending

Patents

Provisional Patents Applications

- “Method and Apparatus for Registering Image Data Between Different Types of Image Data”, Anant Madabhushi, Rachel Sparks, P05561US0.

Invention Disclosures

- “A Texture Based Finite Element Model Registration Scheme For Registering Pre-Treatment Intensity Modulated Radiation Therapy MR Imagery To Post-Treatment MR Imagery”, Anant Madabhushi, Robert Toth, Case 2013-2375.
Awards and Accomplishments in 2012

Professional, Editorial, Activities, Institutional Service – Anant Madabhushi

- Chair, Poster Session Analysis of Microscopic and Optical Images II, MICCAI 2012, October 4th, 2012, Nice, France
- Member of the MICCAI 2012 Young Scientist Award Committee.
- Area Chair, Eight Indian Conference on Vision, Graphics, and Image Processing (ICVGIP) 2012.
- Chair, Prostate Segmentation Challenge, MICCAI 2012.
- Chair, Workshop on Histopathology Image Analysis, MICCAI 2012.
- Advisory Committee, Workshop: Bio-computing, Genomics and Epigenomics, DIMAC, Rutgers University, September 2012.
- Program Committee Member, Imaging Track of the 2nd annual IEEE International Conference on Healthcare Informatics, Imaging and Systems Biology(HISB), 2012.
- Associate Editor, *IEEE Transactions in Biomedical Engineering* 2009-present.
- Associate Editor, *IEEE Transactions in Biomedical Engineering (Letters)* 2008-present.
- Program Committee Member, Asian Conference on Computer Vision (ACCV 2012), 2012.
- Program Committee Member, ASE/IEEE International Conference on BioMedical Computing, 2012.
- Program Committee Member, MICCAI 2012.
- Chair, Conference 8315: Computer Aided Diagnosis, Session on Abdomen Imaging, SPIE Medical Imaging, Feb 2012.
- Chair, Conference 8315: Computer Aided Diagnosis, Session on Digital Pathology I, SPIE Medical Imaging, Feb 2012.
- Chair, Conference 8315: Computer Aided Diagnosis, Session on Digital Pathology II, SPIE Medical Imaging, Feb 2012.
Awards and Accomplishments

Professional, Editorial, Activities, Institutional Service – Anant Madabhushi (Contd.)

- Program Committee Member, Workshop on Machine Learning in Medical Imaging, MLMI'12.
- Program Committee Member, International Conference on Image and Signal Processing, ICISP'12.
- Co-Chair, Workshop on Non-invasive imaging/imaging phenome, American Society for Investigative Pathology, San Diego, 2012.

Awards

- Runner Up for Investors Choice Award, New Jersey Entrepreneurial Network (NJEN), 2012.

Media Recognition

New Grants-2012

Madabhushi, Anant (PI)
Date: 9/12/12-8/31/14
NIH R21CA167811-01
Decision support with MRI for targeting, evaluating laser ablation for prostate cancers
Role: PI

Madabhushi, Anant (PI)
Date: 01/01/13-12/31/13
QED Grant, University City Science Center
ProstaCAD™: Computer based detection of Prostate Cancer from MRI
Role: PI

Madabhushi, Anant (PI)
Date: 07/01/12-06/31/13
Proof of Concept Award, Rutgers
Computerized Decision Support for Prostate Cancer Detection and Treatment via Multi-parametric MRI
Role: PI

Buckler, Andrew (PI)
Date: 01/01/13 - 06/01/13
NSF SBIR Phase 1
Computer assisted prognosis of debilitating disease
Role: Co-PI (Madabhushi)
Student, Post-doctoral Awards and Fellowships

- Andrew Janowcyz, Travel award ($500) to attend HIMA Workshop in conjunction with MICCAI 2012.
- Robert Toth, Travel award ($2000) to attend USA-Sino Summer School in Vision, Learning, Pattern Recognition: VLPR 2012 (Theme: Computer Vision in Biomedical Image Applications: From Micro to Macro), 2012
- Angel Alfonso Cruz Roa, MICCAI Travel Award ($600), 2012.
- Eileen Hwuang, First Place (Overall) for Best Student Research Presentation ($250), SOE Research Symposium, Rutgers University, 2012
- Joseph Galero, Fulbright Fellowship, 2012
- Najeeb Chowdhury, “Concurrent segmentation of the prostate on MRI and CT via linked statistical shape models for radiotherapy planning”, Highlighted in Medical Physics Editors Pick Column.
- Elaine Yu, NSF Graduate Research Fellowship, 2012
- Joseph Galero, Honorable Mention, NSF Graduate Research Fellowship, 2012
- Rachel Sparks, Cum laude for Best Poster Presentation at the Computer Aided Diagnosis (CAD) Conference, SPIE Medical Imaging, 2012
Active Research (32 projects)

Methods

Multimodal Data Integration and Evaluating Therapy

Computer Aided Diagnosis and Prognosis

Image Segmentation
Image Registration
Machine Learning
Image Reconstruction

Radiology
Histopathology
Bioinformatics

Prostate Cancer
Breast Cancer
Brain Glioma
Carotid Plaque

Medulloblastoma
Oropharyngeal
Epilepsy
Myelodysplasia
IMAGE SEGMENTATION
Spectral Embedding based Active Contour (SEAC) for Lesion Segmentation on Breast MRI

(a) Original grayscale post-contrast image and image representations derived from (b) FCM and (c) SE. Note that the colormaps displayed for both methods only reflect the voxel similarities and determined by the 2 schemes, voxels with similar time-intensity curves being assigned similar colors. The second row of images shows the ground truth segmentation (e) in red and the hybrid AC segmentation driven by (f) the FCM+AC segmentation overlaid (yellow line) on ground truth, (g) PCA+AC segmentation, and (h) SEAC segmentation overlaid on ground truth.

Quantitative results obtained from the SEAC segmentation compared to the FCM+AC, and PCA+AC methods.

<table>
<thead>
<tr>
<th>Segmentation Method</th>
<th>$AUC (\mu \pm \sigma)$</th>
<th>$AC$ Method</th>
<th>$MAD (\mu \pm \sigma)$</th>
<th>$DSC (\mu \pm \sigma)$</th>
<th>$HD_{max} (\mu \pm \sigma)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>FCM + AC</td>
<td>0.50 ± 0.07</td>
<td>FCM + AC</td>
<td>6.64 ± 6.37</td>
<td>0.50 ± 0.32</td>
<td>11.86 ± 10.14</td>
</tr>
<tr>
<td>PCA + AC</td>
<td>0.49 ± 0.07</td>
<td>PCA + AC</td>
<td>*3.11 ± 3.09</td>
<td>*0.73 ± 0.22</td>
<td>8.17 ± 7.36</td>
</tr>
<tr>
<td>SEAC*</td>
<td>0.67 ± 0.05</td>
<td>SEAC</td>
<td>*2.31 ± 2.26</td>
<td>*0.74 ± 0.21</td>
<td>*5.64 ± 5.04</td>
</tr>
</tbody>
</table>

Simultaneous Segmentation of Prostatic Zones Using Active Appearance Models with Multiple Coupled Levelsets

- Use of Active Appearance Models (AAM’s) to couple multiple levelsets using PCA
- Simultaneous segmentation of prostate, central gland (CG), peripheral zone (PZ).

Image Segmentation with Implicit Color Standardization Using Spatially Constrained Expectation Maximization: Detection of Nuclei

Most EM-based algorithms ignore spatial constraints. Thus, we presented spatially-constrained EM (SCEM), a novel approach for incorporating Markov priors into the EM framework. We validated SCEM by integrating it into our computerized system to segment nuclei in H&E stained histopathology.

Color nonstandardness – the propensity for similar objects to exhibit different color properties across images – poses a significant problem in digital histopathology. We developed a unique instantiation of the expectation maximization (called cascaded EM) to help create a novel color segmentation algorithm which is robust to nonstandardness. We validated our algorithm by detecting myelodysplastic syndrome on bone marrow specimens.

A Region-boundary and Shape based Active Contour

Hybrid Active Contour scheme that can simultaneously segment overlapping and non-overlapping objects.

**Goal:** Improve color constancy across histology images by realigning color distributions to match a pre-defined template.

(a) A new histopathology image is standardized to (b) a template image using the (c) Expectation Maximization algorithm to decompose the image into tissue classes. (d) Color histograms are aligned separately for each class and subsequently recombined to form a standardized image. Green outlines illustrate how standardization yields more consistent segmentation of nuclei. In addition, histograms demonstrating alignment of multiple images (a) before and (d) after standardization.
Multi-Feature, Landmark-Free Active Appearance Models (MFLAAM)

- Levelset function used to create statistical shape model in an AAM framework.
- Generalized AAM’s to incorporate image derived attributes such as gradient or texture information – only considered intensities previously
- “Registration”-like template matching scheme to locate prostate

IMAGE REGISTRATION
**Prostatome™: Prostate Imaging Atlas via Anatomic Constrained Registration**

Statistical Models for the Anatomic Structures:
- Prostate capsule
- Central Gland
- Peripheral Zone

Distribution of cancer:
- High frequency
- Medium
- Low

M. Rusu, B. N. Bloch, C. C. Jaffe, N. M. Rofsky, E. M. Genega, R. E. Lenkinski, A. Madabhushi, Statistical 3D prostate imaging atlas construction via anatomically constrained registration, Accepted SPIE 2013
A Statistical Deformation Model (SDM) based Regularizer for Non-rigid Image Registration: Application to registration of multimodal prostate MRI and histology

- Regularizer needed in registration to allow for a physically meaning transformation.
- Here, we leverage knowledge of known, valid deformations to train a statistical deformation model (SDM)
  - Harness this knowledge alongside FFD to provide an accurate overlay of histology on MRI.

Incorporating the Whole-Mount Prostate Histology Reconstruction Program Histostitcher© into the Extensible Imaging Platform (XIP) Framework

• Histostitcher algorithm incorporated into professional XIP software framework.
• GPU rendering, “Google Maps” – like zooming, scrolling

Previous version of Histostitcher© graphical user interface usable prototype developed using Matlab.

New version of Histostitcher© graphical user interface developed using XIP.

Fully-Automated T2 W MRI-TRUS Fusion

**Objective:** Registration of MRI-TRUS with no manual intervention

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**Module 1. MRI Prostate Segmentation**

**Module 2. TRUS Probabilistic Model of Prostate Location**

- (a) Spatial Prior
- (b) Estimation of texture-base pixel-wise probability

**Module 3. Register Model to Segmentation**

- (a) Affine Registration
- (b) Elastic Registration

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CASE SCHOOL OF ENGINEERING
CASE WESTERN RESERVE UNIVERSITY
Learning-based Landmark Driven Image Registration

The objective of this work is to develop an effective approach to estimate an optimal landmark configuration in order to drive point-based non-rigid image registration schemes.

The difference map between: (a) the original and deformed images, and (b), (c) the original and registered images using ICP-based, and FFD methods, respectively.

Co-registration of MRI via a Learning Based Fiducial-driven registration (LeFiR) Scheme

(A)(B), (G)(H) pre- and post-treatment brain images, (C)(I) identified landmarks, (D)(J) uniformly spaced landmarks, and difference images between pre- and registered images using (E)(K) identified landmarks, (F)(L) uniformly spaced landmarks.

Mouse Lung Reconstruction from Groupwise Registration of Individual Histological Slices with Natural Gradient

- Perform groupwise registration of individual histological slices.
- Present a fast incremental Lucas-Kanade computation framework.
- Integrate natural gradient for faster and more reliable convergence.

Fig. 1 Reconstructed volumes

Fig. 2 Convergence curves of registration approaches

Haibo Wang, etc., Mouse Lung Volume Reconstruction from Efficient Groupwise Registration of Individual Histological Slices with Natural Gradient, SPIE 2013.
Fusion of histological and MRI lung volumes

Multiscale, multimodal fusion of histological and MRI lung volumes for characterization of airways, M. Rusu, H. Wang, T. Golden, A. Gow, A. Madabhushi, Accepted SPIE 2013
MACHINE LEARNING
Class-Specific Weighting for Markov Random Field Estimation

Methods for varying the performance of MRFs is conspicuously absent from the literature. Thus, we introduced multiplicative weighted MAP estimation for MRFs.
Comparing Classifier Schemes for CaP Detection from T2w MRI

Empirically compared 12 different classifier schemes for detecting prostate cancer on a per-voxel basis using textural representations of T2w MRI. Simple QDA classifier performed comparably to popular complex SVM classifier.

“Computer-aided Detection of Peripheral Zone and Central Gland Prostate Tumors on T2-weighted MRI”, RSNA, 2012
Variable Ranking for PCA

- Quantify the contributions of individual, high dimensional features to a PCA embedding
- Multi-parametric MR imaging markers for prostate cancer:
  - Importance of ADC intensity, in contrast to T2w intensity
  - Importance of Gabor texture features extracted from ADC maps and T2w MRI
  - Importance of choline, polyamine, and citrate metabolites measured on magnetic resonance spectroscopy
- Facilitates the use and interpretation of high dimensional features while avoiding the curse of dimensionality

Statistical Shape Model of Manifolds

- Objective: Accurately model manifold structure

a. Divide dataset into K folds
b. Generate manifold for each fold
c. Learn Model

MULTIMODAL DATA INTEGRATION AND TREATMENT EVALUATION
Radiohistomorphometry™: Correlating DCE-MRI and Microvascular Parameters to Identify in vivo Markers for Prostate Cancer Aggressiveness

Singanamalli et al. To appear in SPIE Medical Imaging 2013
Quantitative Evaluation of Treatment Related Changes on Multi-Parametric MRI after Laser Interstitial Thermal Therapy of Prostate Cancer

Preliminary results of developing a quantitative framework to evaluate treatment-related changes post-LITT on a per-voxel basis (high resolution), via construction of an integrated MP-MRI signature

Above, checkerboard registration results showing alignment of multi-protocol MRI, pre-/post-LITT MRI
Right, difference maps showing significant changes in MR parameters within LITT ablation zone

“Quantitative Evaluation of Treatment Related Changes on Multi-Parametric MRI after Laser Interstitial Thermal Therapy of Prostate Cancer”, SPIE, 2013
**Objective:** To quantitatively evaluate changes in MP-MRI imaging markers (T1-w, T2-w, T2-GRE, T2-FLAIR, and ADC) over the epileptogenic foci, pre- and post- laser interstitial thermal therapy (LITT).

COMPUTER AIDED
DIAGNOSIS AND PROGNOSIS
Pharmacokinetic Modeling for Prostate Cancer Localization

- Iterative multiple reference tissue method (IMRTM) for pharmacokinetic (PK) feature extraction from DCE MRI
  - Patient-specific values for $K_{\text{trans}}$ (volume transfer constant) and $v_e$ (extravascular-extracellular volume fraction) are iteratively estimated for voxels in tissues A and B.
  - No need for arterial input function
  - Does not rely on population-based PK parameters
- Preliminary results shown on the right for a CG tumor
Hierarchical Prostate Cancer Grade Classification

Ground Truth – Study 1
Cancer classification – Study 1
Grade classification – Study 1

Ground Truth – Study 2
Cancer classification – Study 2
Grade classification – Study 2

P. Tiwari, A. Madabhushi et al. Medical Image Analysis (MeDiA) – In press.
Quantifying Local Heterogeneity via Morphologic Scale (MS) 
Distinguishing Tumoral Regions from Stromal Regions

Algorithm

Step 1: For each nucleus of interest
Step 2: Isolate pixels desired for quantification via binary map
Step 3: Compute LMS rays by extending ray at desired heading, tracing around obstructions
Step 4: Convert LMS signature to non-domain specific feature vector via Fourier Descriptors

Output

The MS signature overlaid on a tumor regions in an (a) ovarian, (b) prostate H, (c) breast HE, and (d) prostate HE image, to be compared with the benign signatures in ((i)-(l)), respectively. We can see that in the presented non-tumor regions ((i)-(l)) the MS signature has fewer and smaller objects to obstruct its path, and thus the rays are less tortuous, unlike in the respective tumoral regions ((a)-(d)). This allows a supervised classifier to be able to separate the two classes.

Results

<table>
<thead>
<tr>
<th>Data Type</th>
<th>Breast</th>
<th>Prostate HE</th>
<th>Prostate H</th>
<th>Ovarian</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUC +/- Range</td>
<td>.80 +/- .01</td>
<td>.88 +/- .01</td>
<td>.87 +/- .02</td>
<td>.88 +/- .01</td>
</tr>
</tbody>
</table>

Evaluating the need for intensity artifact correction in MP-MRI for computerized detection of prostate cancer in vivo

Demonstrated that explicit correction of intensity inhomogeneity and drift in all 3 MP-MRI protocols (T2w, DCE, DWI) prior to combining them within a classification scheme will yield improved CaP detection accuracy in vivo.

“Evaluating the need for intensity artifact correction in MP-MRI for computerized detection of prostate cancer in vivo”, SIIM, 2013
A Visual Latent Semantic Approach for Automatic Analysis and Interpretation of Anaplastic Medulloblastoma Virtual Slices

**Goal:** Medulloblastoma Tumor Classification (Anaplastic vs Non-anaplastic) with good classification performance and visual interpretability.

(a) New histopathology images are represented as (b) a histogram of Bag of Features (BOF) according to (c) a dictionary of BOF learning using Haar-based descriptors of patches. (d) A probabilistic latent semantic analysis (pLSA) model is trained with image representation and their classes membership of training dataset in order to (e) predict the probability that a given image belongs to Anaplastic or Non-anaplastic type of Medulloblastoma tumor. Finally, (f) a visual probabilistic map is provided according to regions in the image associated with each subtype.

Co-occurring Gland Tensors (CGT) in Localized Cluster Graphs for CaP Histology

CGTs describe the ability for glands to orient themselves with respect to prostate stroma.

Calculate Gland Direction
Establish Locality
CGT

CaP Recurrence

Lee et al. ISBI 2013 Under Review
Cell Cluster Graph for Prediction of Biochemical Recurrence in Prostate Cancer Patients from Tissue Microarrays

- Novel Cell Cluster graph (CCG) that can quantify tumor morphology
- Extracted features from CCG can predict Biochemical recurrence in Prostate Cancer in 80 patients.

Dec 2012 - Jan 2013

Use of Quantitative Histomorphometry to Classify Disease Progression in HPV-positive Squamous Cell Carcinoma

Using Cell Cluster graphs to differentiate Progressors vs Non-Progressors in p16+ Oropharyngeal tumors

Table 2. Quantitative evaluation of CCG based approach against Voronoi and Delanay, and Texture features [6].

<table>
<thead>
<tr>
<th></th>
<th>Voronoi</th>
<th>Delaunay</th>
<th>Textural</th>
<th>CCG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy</td>
<td>74.4 ± 0.6%</td>
<td>76.7 ± 0.7%</td>
<td>77.7 ± 0.4%</td>
<td>88.2 ± 1.2%</td>
</tr>
<tr>
<td>PPV</td>
<td>77.9 ± 1.4%</td>
<td>74.3 ± 0.5%</td>
<td>79.1 ± 1.2%</td>
<td>85.3 ± 0.5%</td>
</tr>
</tbody>
</table>

Ali, Sahirzeeshan, Lewis, James, Madabhushi, Anant, J Use of quantitative histomorphometrics to classify disease progression in HPV-positive squamous cell carcinoma. J. Clin Oncol 30: 2012 (suppl 30; abstr 73)
INTERESTED IN JOINING CCIPD?

We are always looking for enthusiastic and motivated graduate, undergraduate students and research scientists.

If you think you would be a good fit for CCIPD, send over your complete CV and 3 representative publications to “anant.madabhushi” @ “case.edu”

Follow us on Twitter: @CCIPD_Case