Biomedical Imaging & Analysis

Lecture 1, Fall 2014

Part 1:

Intro to Biomedical Imaging & its Applications

*[**Text**: Ch. 1 of Insight into Images edited by Terry Yoo, et al.]*

Prahlad G Menon, PhD

Assistant Professor

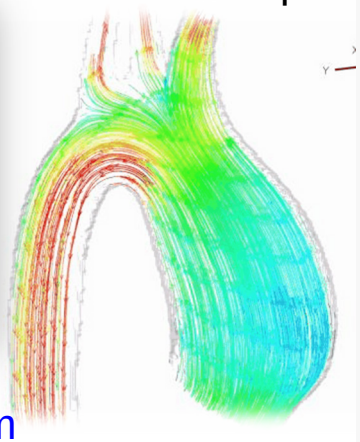
Sun Yat-sen University – Carnegie Mellon University (SYSU-CMU)

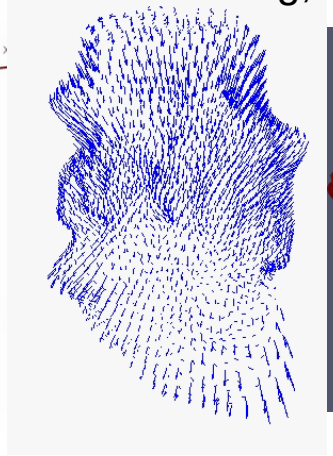
Joint Institute of Engineering

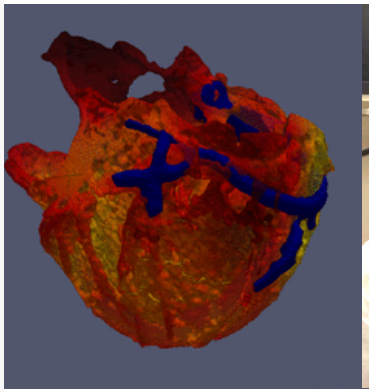
Who is this guy..?

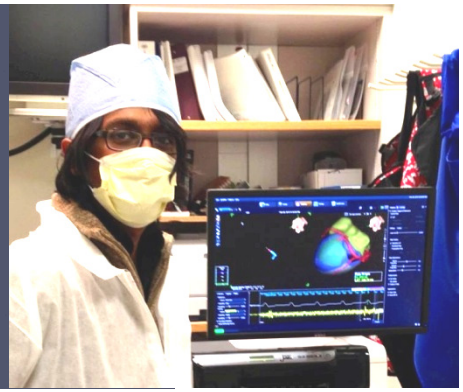
NCBI: http://www.ncbi.nlm.nih.gov/myncbi/prahlad.menon%20gopalakrishna.1/cv/3610/

- Director of The MeDCaVE research program (www.justcallharry.com), strategically positioned at the confluence of physics based computational modeling, informatics, radiology, surgical practice.









www.justcallharry.com

Post Doc. *Biomedical Informatics, University of Pittsburgh, 2013-14.*

Ph.D. *Biomedical Engg.,*
Carnegie Mellon University, *2013*

M.S. *in Mechanical Engg.*
Carnegie Mellon University, *2010*

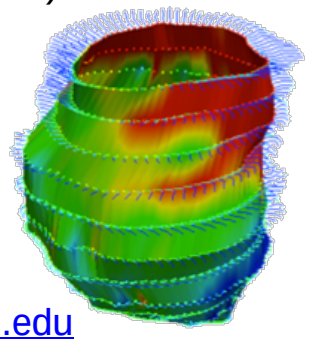
B.Tech. *Mechanical Engg.*
National Institute of Technology
Karnataka, India, *2009*

Prahlad G. Menon, PhD | Founder & CEO, QuantMD, LLC
Assistant Professor, Electrical & Computer Engg.
Sun Yat-sen University - Carnegie Mellon University (SYSU-CMU)
Joint Institute of Engg. (JIE) & Joint Research Institute (JRI)

Assistant Professor (Adjunct), Biomedical Engineering
University of Texas at San Antonio (UTSA)

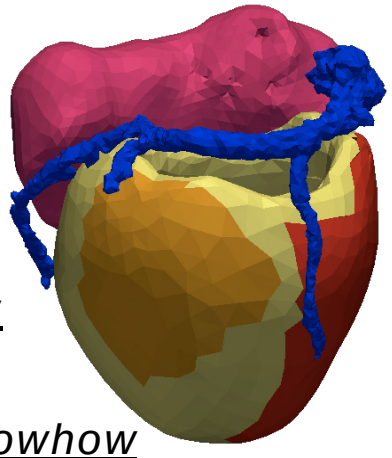
Assistant Professor (Adjunct), Bioengineering
University of Pittsburgh (PITT)

PI: The MeDCaVE | Email: pgmenon@andrew.cmu.edu
Phone: +1 412.259.3031 | Web: www.justcallharry.com



The MeDCaVE

Carnegie Mellon University

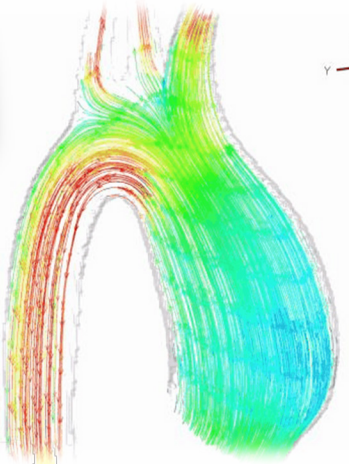


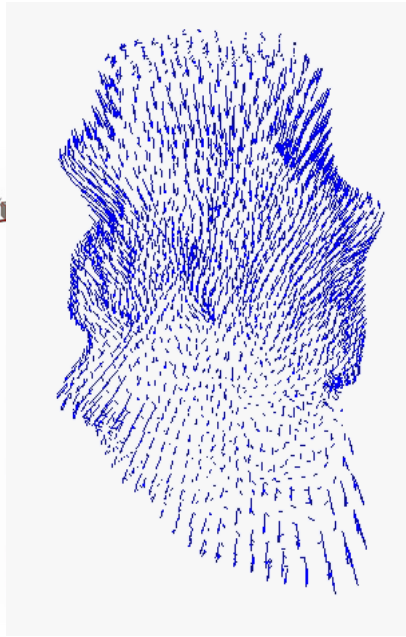
Quantitative imaging based evaluation of :

Patient-specific ***Morphology, Function and Flow***

***B**ig Data + Innovative Software + Physics & Clinical knowhow*

DRIVING TIMELY INTERVENTION,
PLANNING / GUIDING SURGERY
FOR IMPROVED OUTCOMES

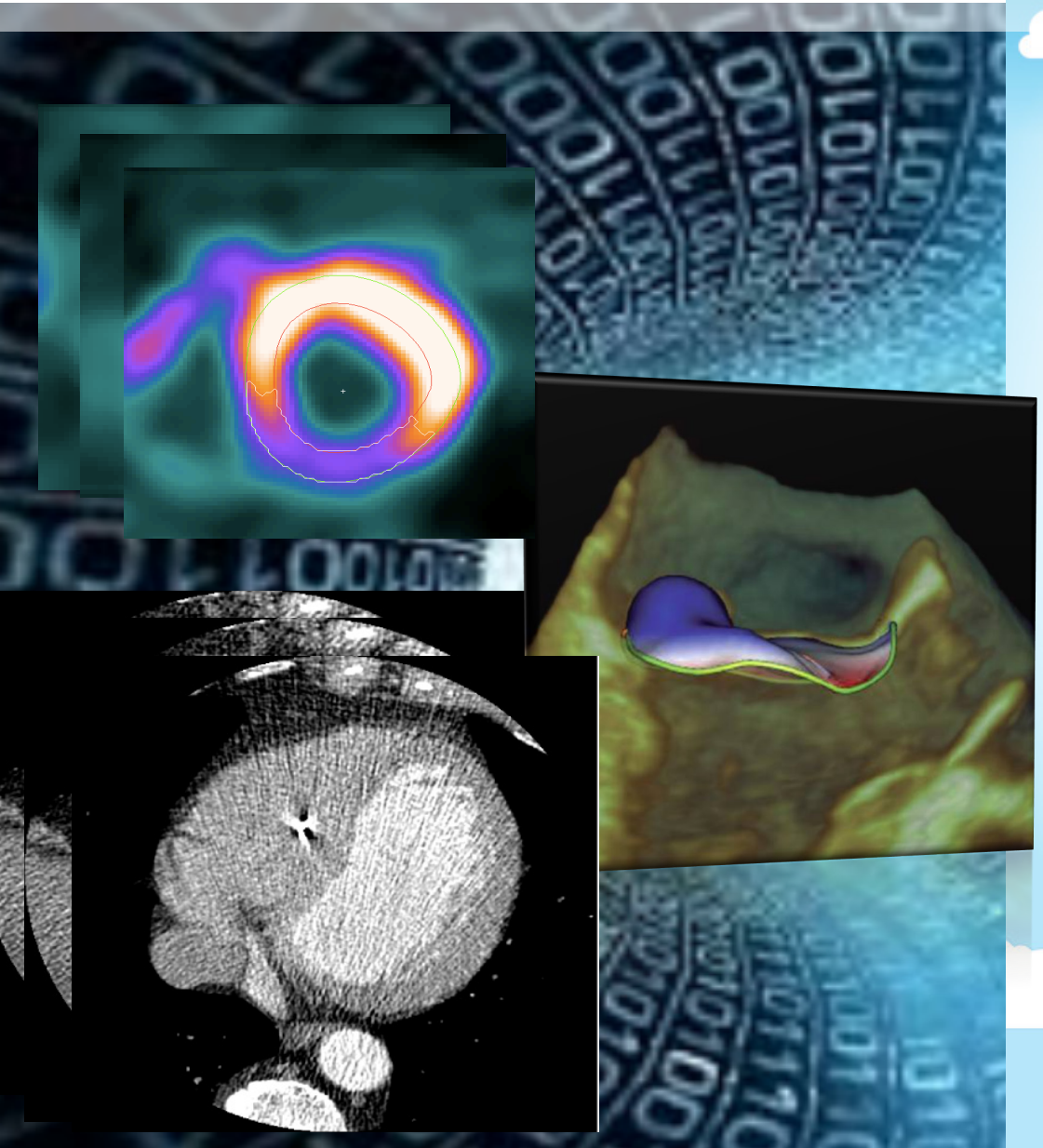




QUANTITATIVE MEDICAL DIAGNOSTICS

The cutting edge in assessing cardiac health

The Biggest Big Data



The Power of Healthcare Data

The Body as a Source of Big Data

Today data storage is essential for healthcare providers to see a patient's complete story of care, make the most informed decisions and enhance treatment and outcomes.

Access to electronic patient data beyond the desktop

3D MRI 150MB

X-RAY 30MB

MAMMOGRAMS 120MB

3D CT SCAN 1GB

0.5MB is generated

It is estimated that by 2015, the average hospital will generate **665TB** of data [1]

There are currently **425K** telehealth providers in the U.S. [2]

PACS (picture archiving and communication systems) applications were cited as the number-one reason for healthcare data growth, at 63 percent, followed by files held in the electronic health record (54 percent) and scanned documents such as proof of insurance (51 percent) [3]

Common uses of health care analytics: More accurate diagnoses, streamlining the cost of care, revenue reimbursement, outcomes and business analysis to manage populations [4]

The Medicare and Medicaid Electronic Health Record Incentive Program now includes a measure for recording imaging results via certified EHR technology. [5]

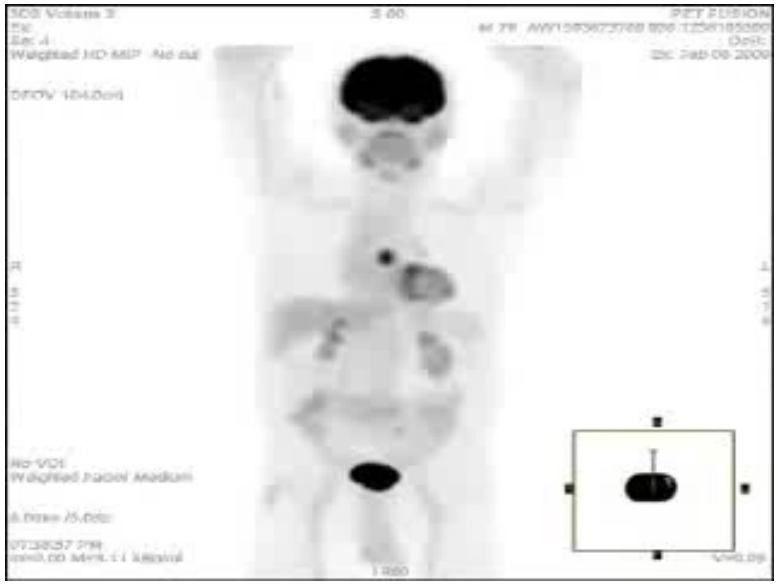
36.6M Total admissions in U.S. registered hospitals, according to the American Hospital Association [6]

Medical image archives are increasing by **20-40%** annually [7]

Today, **80%** of data is unstructured, such as images, video and email. [8]

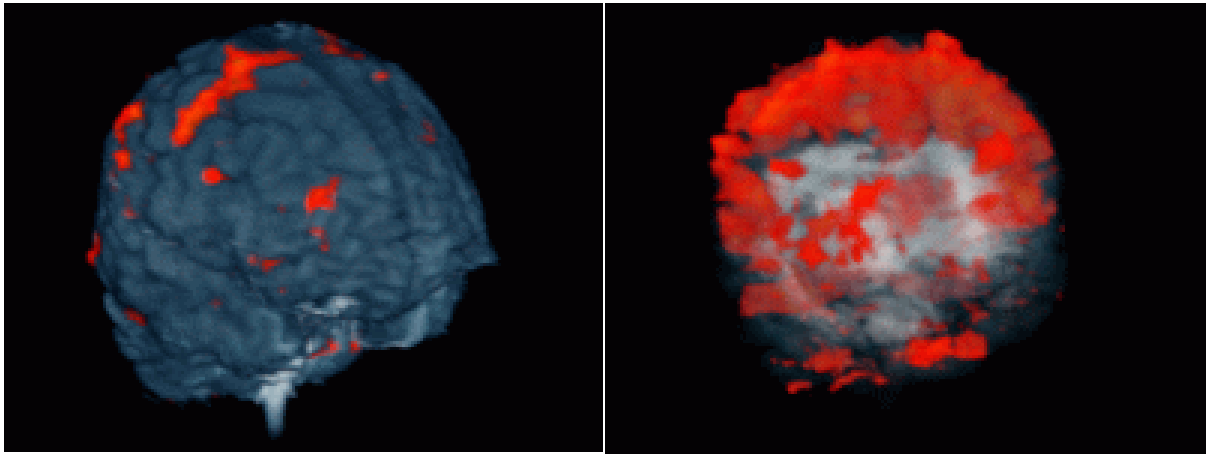
More Examples of Biomedical Imaging

3D rendering of tumor for surgical planning (MRI)



Tumor Metastasis localization (PET)

fMRI of whole brain activation :

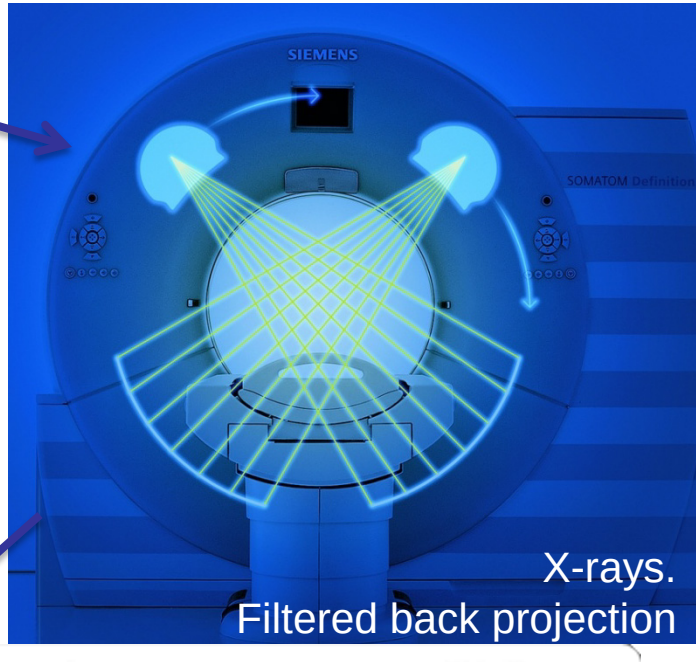


http://nobelprize.org/educational_games/physics/imaginglife/narratives.html

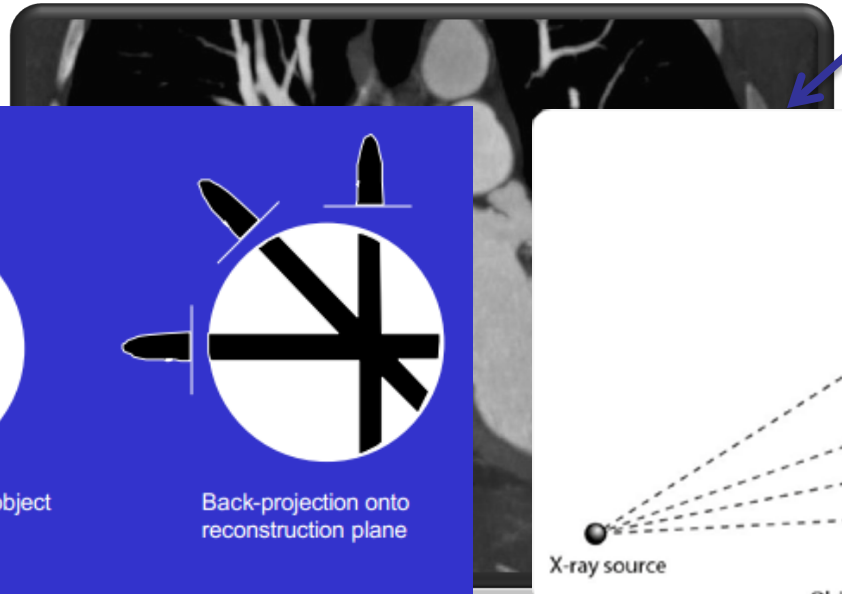
Abundance of Medical Imaging Data

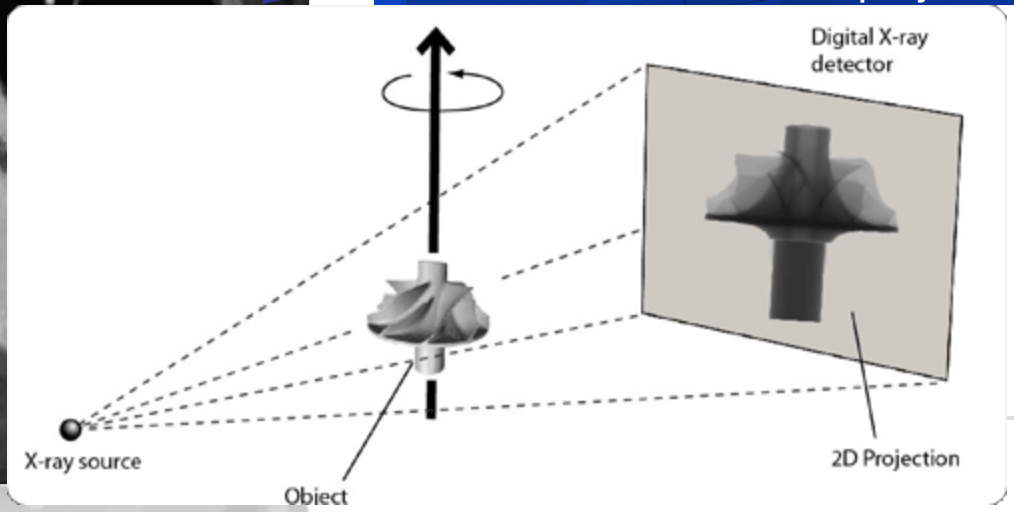
CT: Physics meets Clinic (Part I): *Doing more for clinicians.*

http://www.youtube.com/watch?v=ra7sw0kNvTw

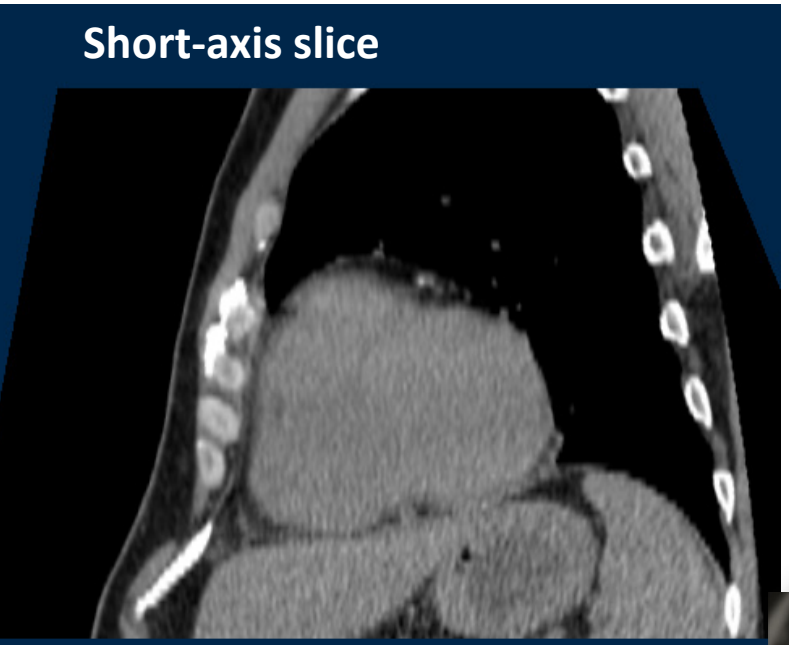


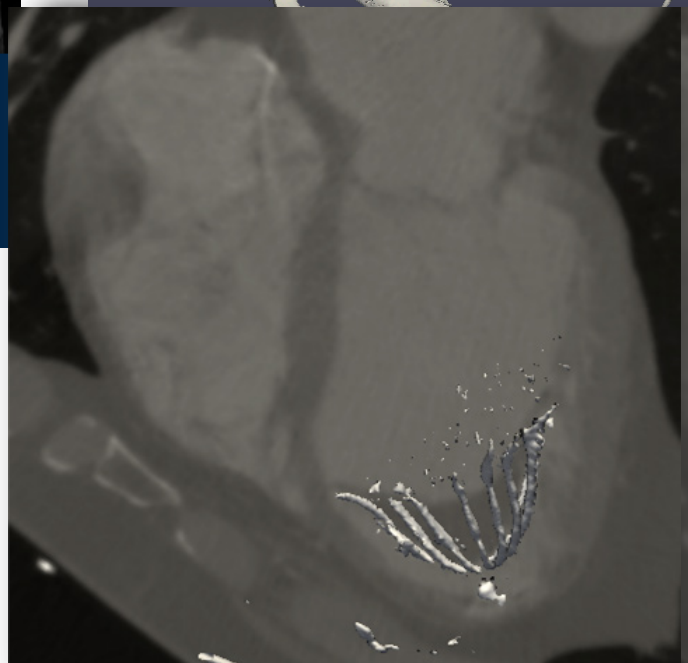
X-rays.
Filtered back projection

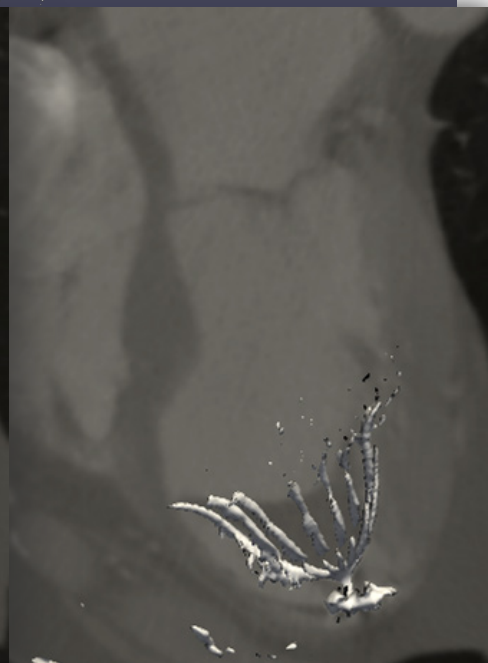




What CT Image data look like ..?



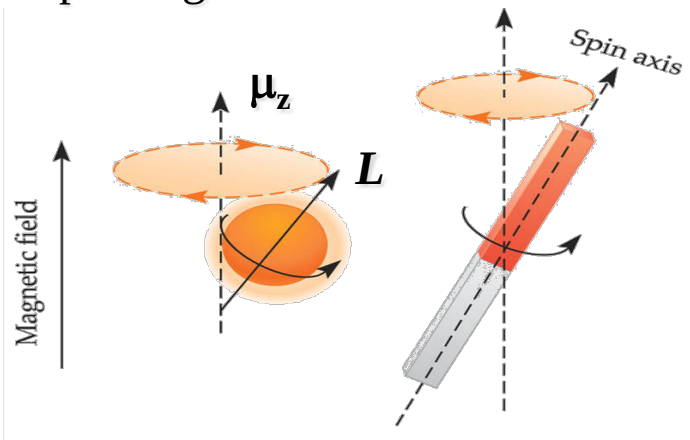




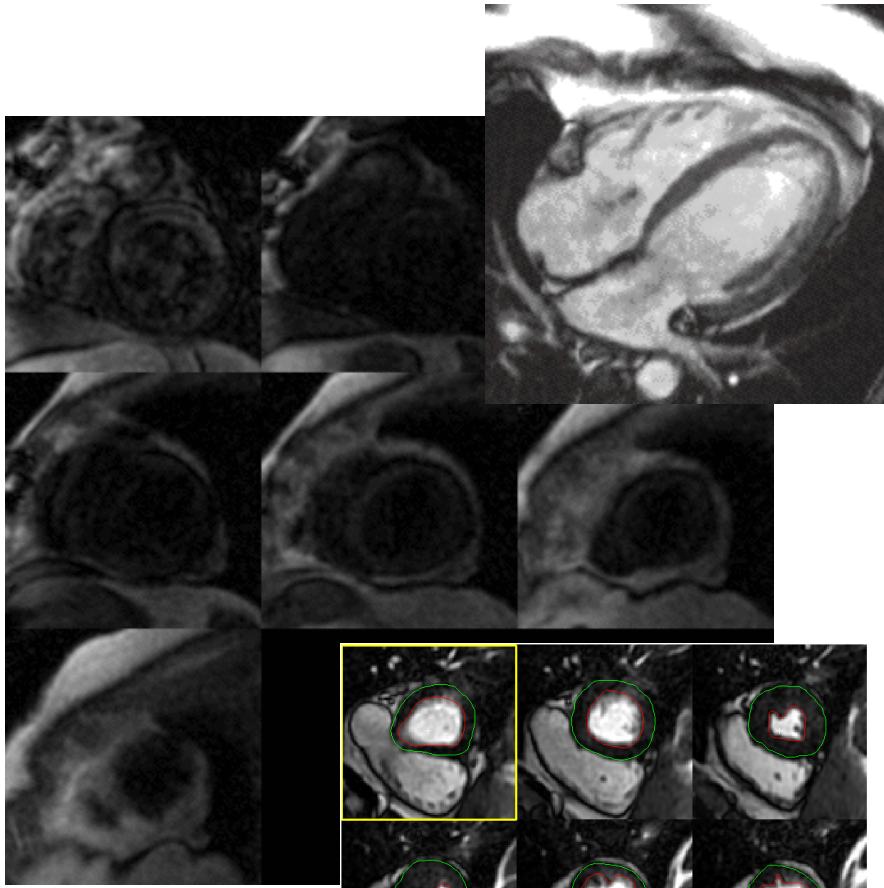
How are these images formed..?

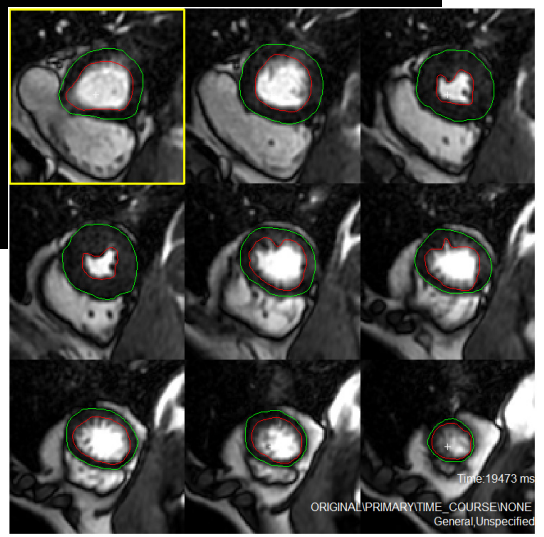
MRI: Physics meets Clinic (Part II)

The proton has mass and an angular momentum ***L*** when it is spinning.



An Introduction to MRI Physics and Analysis Michael Jay Schillaci, PhD

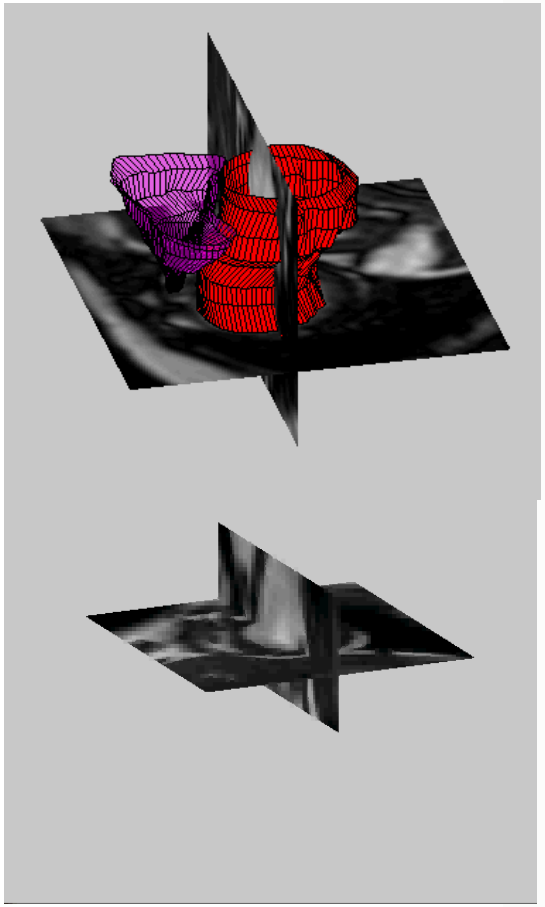


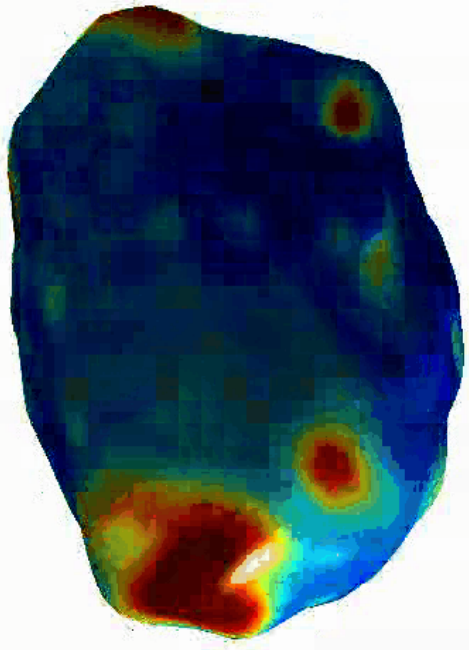


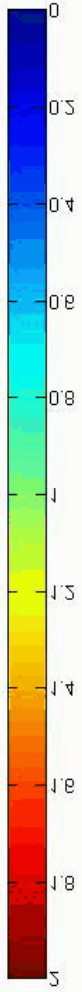
- The electric charge of the proton creates a small current loop since the proton is constantly in motion and this generates a magnetic moment μ = current times the area of the loop.
- In the presence of a static external magnetic field the protons try to align (or anti-align) with the applied field.
- MR measures the net *magnetization* of atomic nuclei which be manipulated by changing the magnetic field environment.

Decision Support

Confluence of Quantitative Analysis and Radiology







Starting with standard imaging

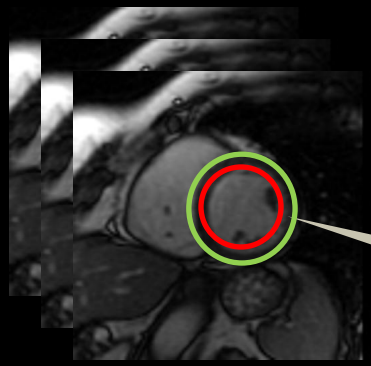
Shape-driven function Analytics

4D Strain, displacement, Dyssynchrony

Stratifying Heart Disease based on Wall Motion Function

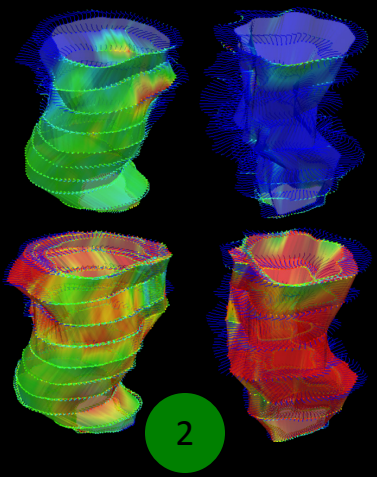
Tried & Tested

1) www.jcmr-online.com/content/16/S1/P385
2) http://proceedings.spiedigitallibrary.org/proceeding.aspx?articleid=1852470



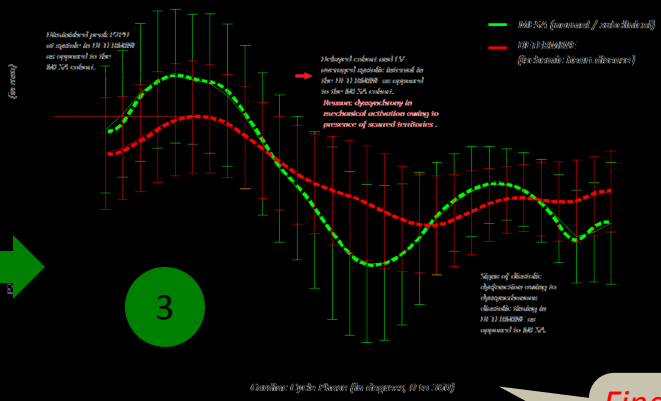
Segmentation

1



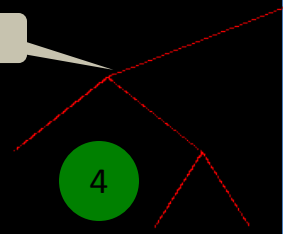
2

Regional wall motion characterization



3

Classification



4

*Fingerprint of cardiac function – **P2PD** characteristics*

Carnegie Mellon

Menon Medical Diagnostics & CardioVascular Engineering
700 Technology Drive, Pittsburgh, PA:15219, Tel: +1 (412) 259-3031

Electrical & Computer ENGINEERING

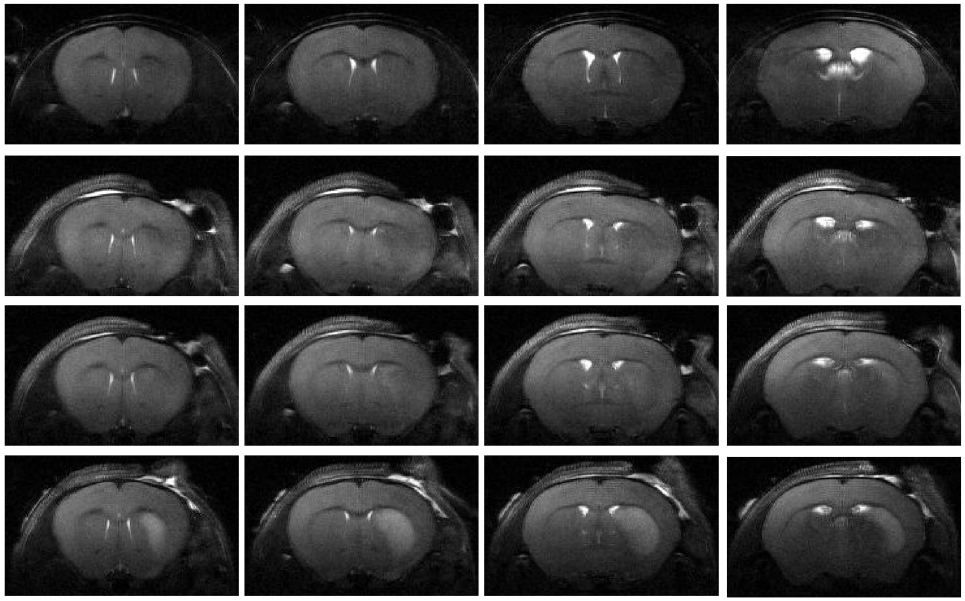
CONTACT:
pgmenon@andrew.cmu.edu
www.justcallharry.com

Prahlad G Menon, Ph.D : Assistant Professor
Electrical & Computer Engineering, Carnegie Mellon University

Advantage of Most Bio-imaging v/s tissue analysis ? ***NON-INVASIVE!***

Mice subjected to 30 min of stroke:

- Assessed using MRI before and 3-24h after.



Histology: Tissue is fixed, cut into slices, then subjected to a dye. The resulting sections are then analyzed.

Imaging advantages

Relative to histology or invasive tissue analysis

1. Rapid acquisition of the information
2. Non-destructive, i.e. minimal perturbation
3. In situ or in vivo
4. Repetitive (longitudinal) studies possible

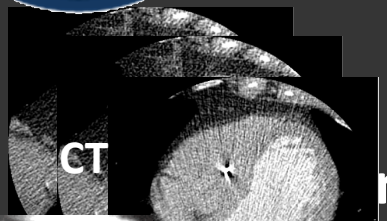
Ultrasound of mouse heart

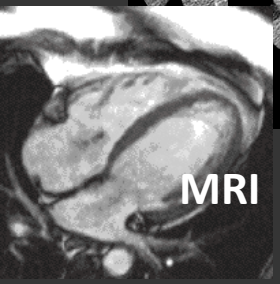
Slide adapted from EPFL, Fund BioImag 2013

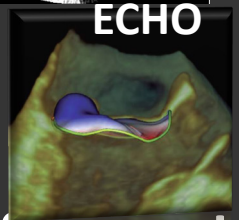
More than Quantitative

Virtual Physics Simulation!

Carnegie Mellon University



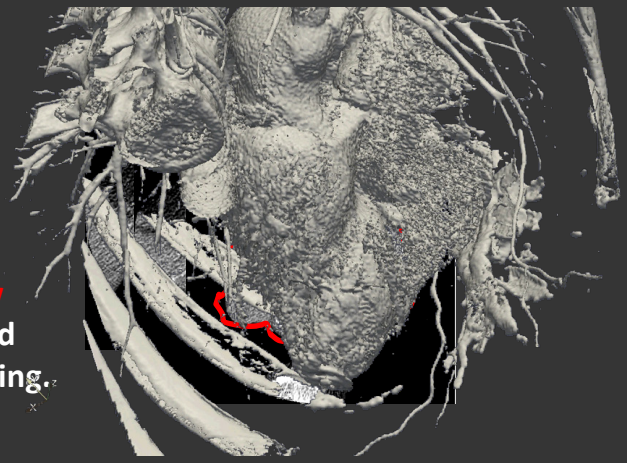




Input image data

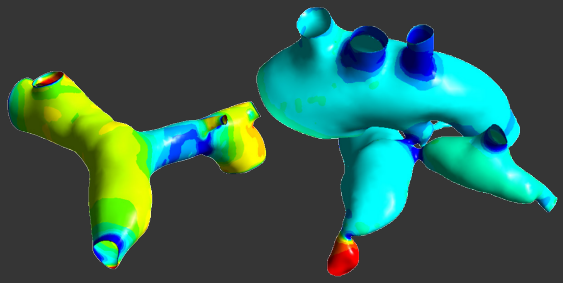
Segmentation

Interactively regionally grow anatomy using level-set based region partitioning and contouring.



Solve internal flow given *boundary condition* choices using validated high-performance immersed boundary flow solver

– preceded by meshing!



ParaView

EnSight

tecplot Master the View

Custom Plugins – open source! for post-processing flow structures.

Write output files

Compatible with range of commercial & open-source visualization tools.

How is the course organized

- Image **Formation**
- **Basic** Image Processing
  - Applications in Machine Vision & Feature Extraction
  - Feature Classification
- **Advanced** Image Processing Topics
  - Shape Analysis, Registration, Mutual Information
  - Optical Flow & Physics based image processing / Regularization
  - Shape and Appearance Models

TEXT BOOKS

- *Basic:* *Machine Vision by Wesley E. Snyder & Hairong Qi*

- *Advanced:* *Insight into Images edited by Terry Yoo, et al.*

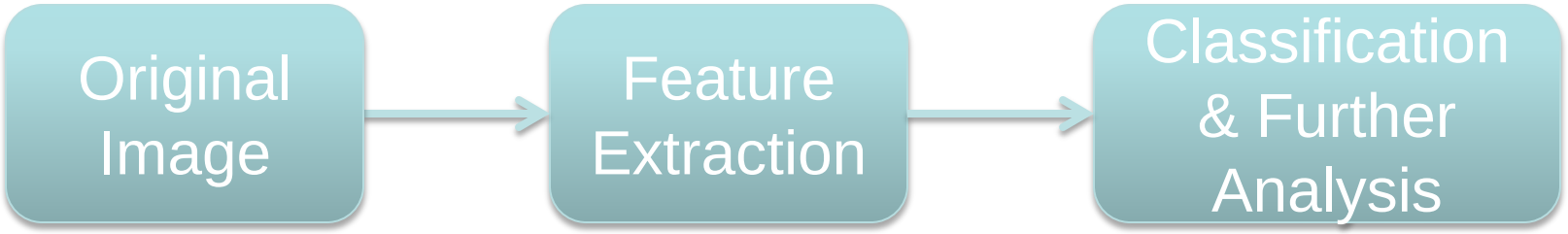
Image Formation Topics

- Signal to Noise v/s Contrast to Noise
- System's model of an Imaging Device.
- X-ray & CT
  - Tomographic Reconstruction Techniques
- Fluoroscopy
- MRI
- Optical Imaging
  - Resolution limits
  - Point Spread Functions

Basic Image Processing Topics

- Linear Operators for image Enhancement
- Coding
  - Compression
- Restoration
  - “Fix” an image
  - Requires model of image degradation
- Image Segmentation & 3D Reconstruction

Applications: Machine Vision



- AKA:
  - Computer vision
  - Image analysis
  - Image understanding
- Pattern recognition:

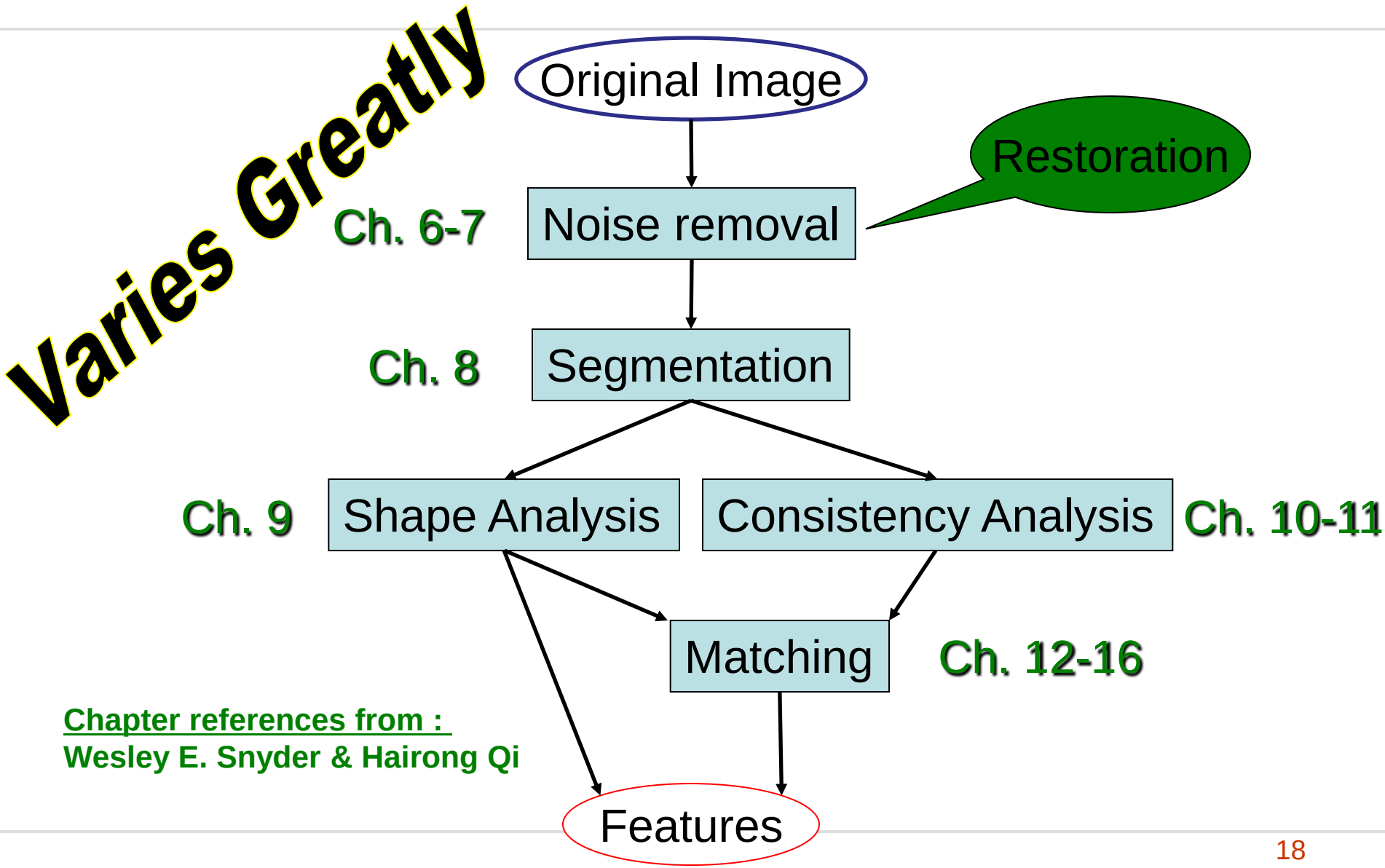
1. Measurement of features

   Features characterize the image, or some part of it

2. Pattern classification

   Requires knowledge about the possible classes

Sample Feature Recognition Pipeline



Chapter references from :
Wesley E. Snyder & Hairong Qi

Advanced Image Processing Topics

- Image Registration
  - Mutual Information
  - Physics-based methods & Regularization
- Shape / Morphology Characterization
  - Spherical Harmonics
  - Laplace Eigen Modes & PCA
- Active Shape & Appearance Models

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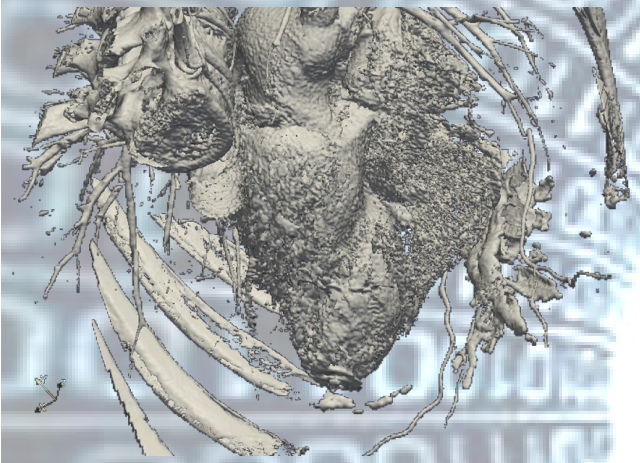

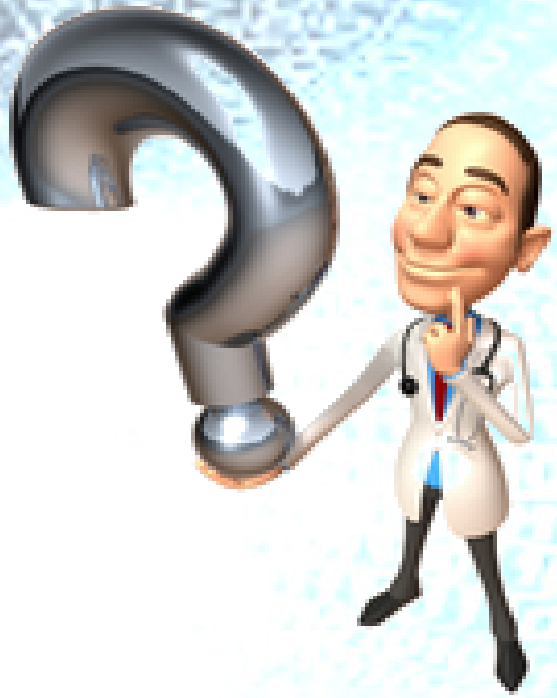

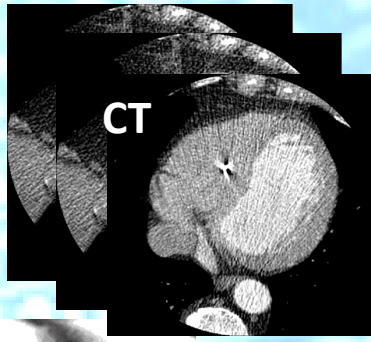

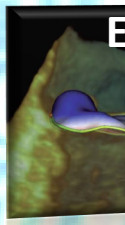

Prahlad G Menon, PhD

www.justcallharry.com

+1 412-259-3031

pgmenon@andrew.cmu.edu