Tissue Characterization by Image Analysis for Diagnosis Purposes
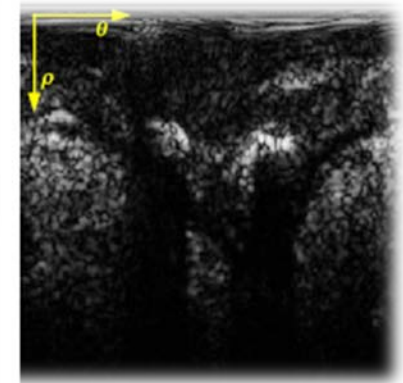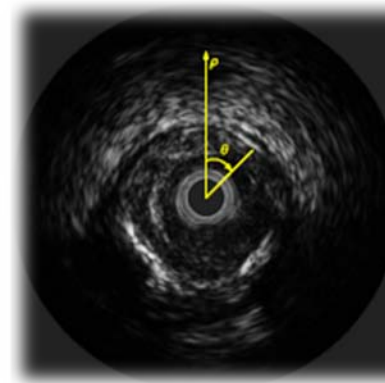
J. Miguel Sanches (PhD)

Assistant Professor

Institute for Systems and Robotics

Bioengineering Department (DBE)
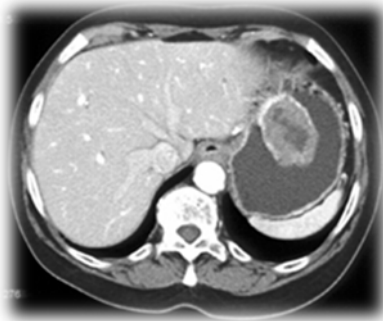Instituto Superior Técnico / Technical University of Lisbon

email: jmrs@ist.utl.pt
home: www.isr.ist.utl.pt/~jmrs

Medical Imaging

Different Biomedical Image Modalities are corrupted and distorted by different types of noise
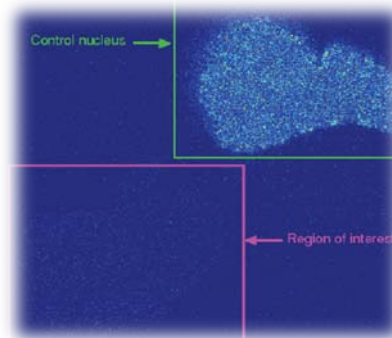
(IV)US

CT

LSFCM

MRI/ASL

MRI

Noise

- Is usually discarded because it is unwanted and purposeless
- Is generated during the acquisition process and/or processing
- Is stochastic and is usually described from a statistical point of view, e.g., first or higher order statistics
- Is difficult to eliminate
- **It is usually very difficult to decide what is noise/artifact what what is not**

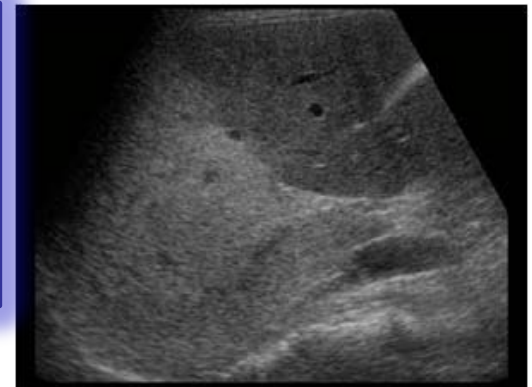**But it can contains useful information about the observed object**

Image Distortion and Noise
Observation model
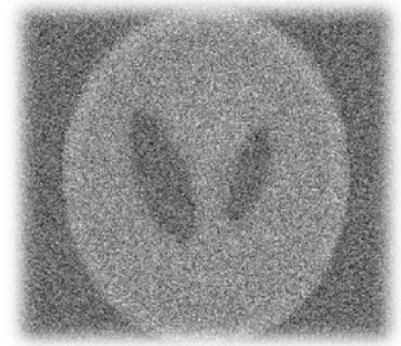
Typical effects/models

$$y = f(x)$$

x $w = Hx$ $z = \log(w + 1)$ $y = z + \eta$

Original   Blurred   Non linear distortion   Noise

(Usual) Goal

Estimate x from y

$$\hat{x} = f^{-1}(y(x)) = g(y(x))$$

x — Original

y — Noisy and distorted observation

$\hat{x}$ — Estimated

Ill-posedness

$$\hat{x} = g(y)$$

- Estimating x from y is usually an ill-posed inverse problem
- A problem is ill-posed if it is not well-posed.
- The problem is well-posed, according Hadamard, if
  - A solution exists
  - The solution is unique
  - The solution depends continuously on the data

Example

$$\hat{x} = \arg\min_{x} E(y, x)$$

Mathematical Characterization
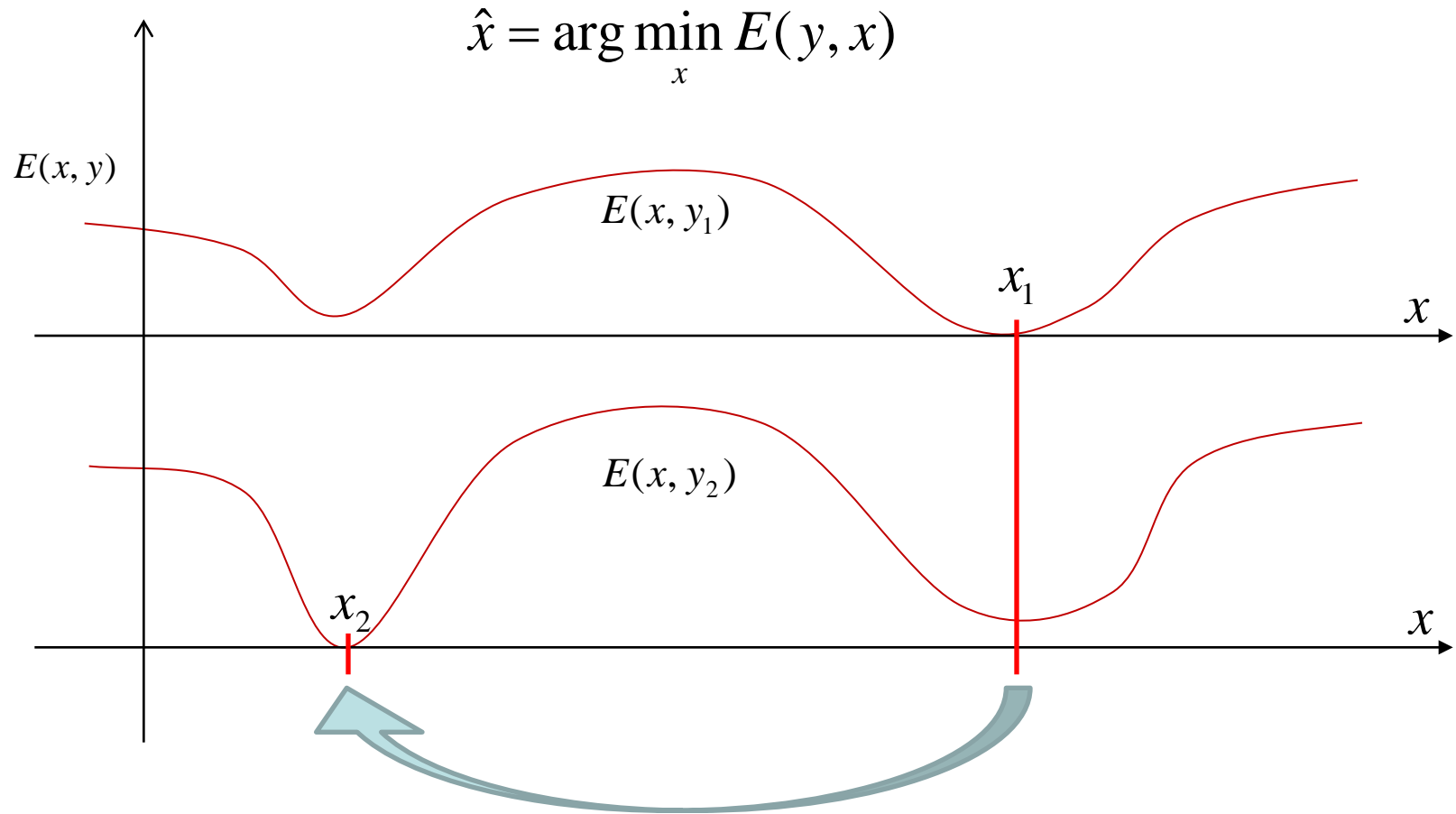
$$Y \approx p(Y, \theta(X)), \qquad Y = \{y_i\}$$

- Noise Characterization:
  - Additive/Multiplicative/Other
  - White / Colored

e.g. White and Gaussian

White: $\quad p(Y \mid \theta(x)) = \prod_i p(y_i \mid \theta_i(x_i))$

Gaussian: $\quad p(y_i \mid \theta_i(x_i)) \approx N(x_i, \sigma^2)$

AWGN

Additive White Gaussian Noise

$$y_i = x_i + \eta_i$$

$$p(\eta_i) \approx N(0, \sigma^2)$$

$$p(y_i \mid \theta_i(x_i)) \approx N(x_i, \sigma^2)$$
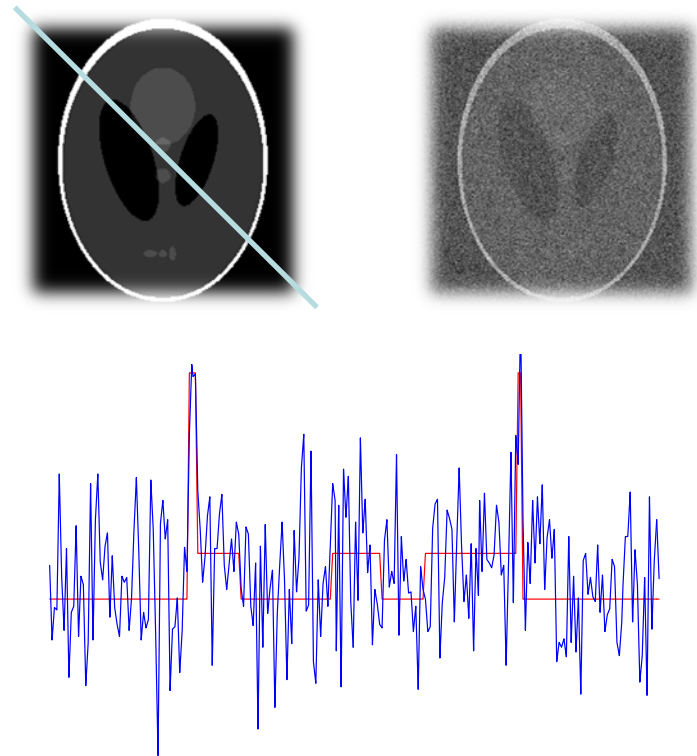
Multiplicative White Gaussian Noise

$$y_i = x_i \eta_i$$

$$p(\eta_i) \approx N(0, \sigma^2)$$

$$p(y_i \mid \theta_i(x_i)) \approx N(0, x_i^2 \sigma^2)$$
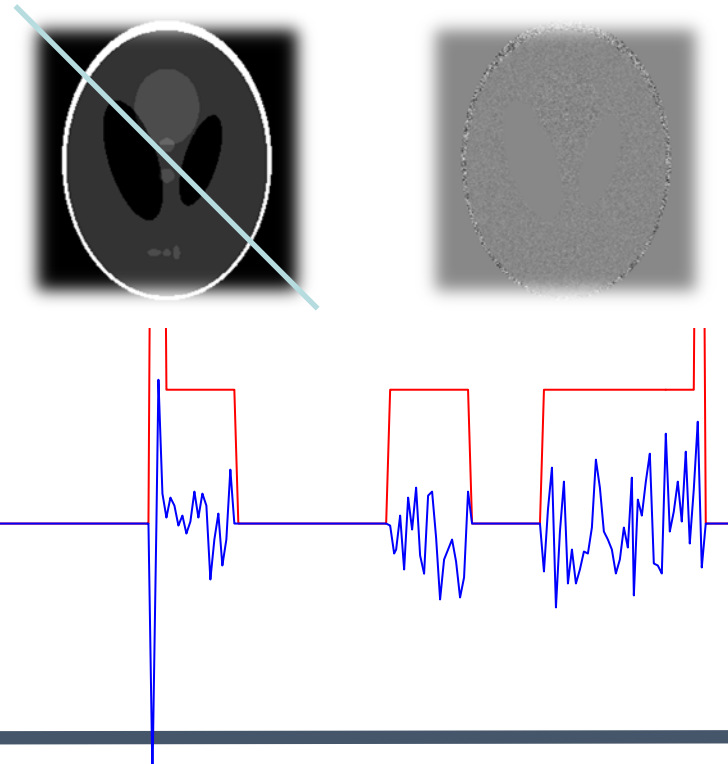
Multiplicative White Rayleigh Noise

$$y_i = x_i \eta_i$$

$$p(\eta_i) = R(\eta_i, 1)$$

$$R(y, x) = \frac{y}{x} e^{-\frac{y^2}{2x}}$$

$$p(y_i \mid \theta_i(x_i)) \approx R(x_i)$$
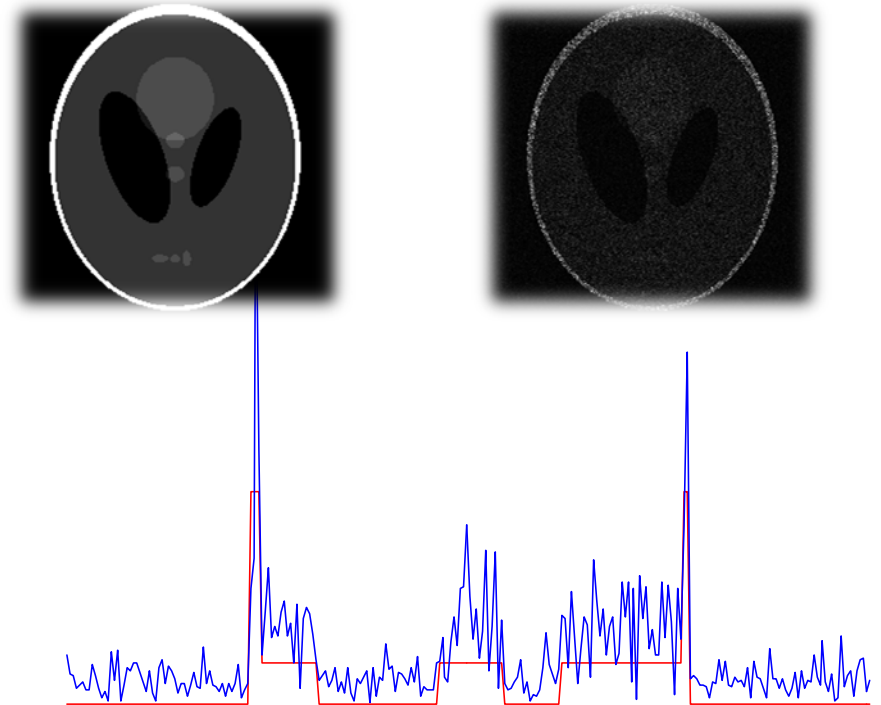
Multiplicative in Wide Sense

- Variance depending on Signal
- Not necessarily multiplicative in the algebraic sense

$$p(y \mid \theta(x)) \approx Poisson(y, x) \approx \frac{x^y}{y!} e^{-x}$$

The Variance depends of the observation (signal); it is not constant
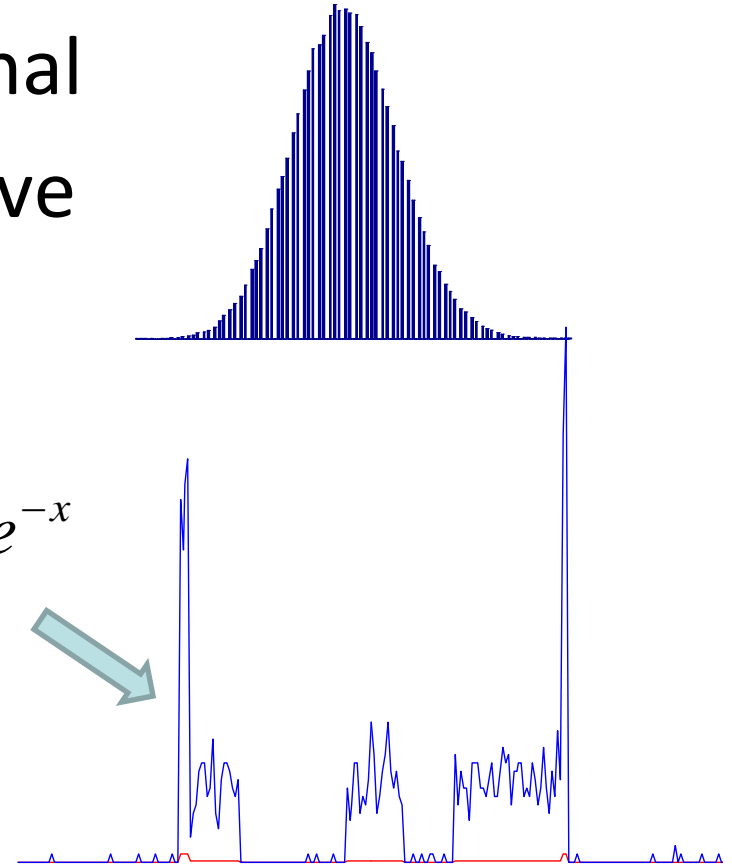
Speckle

- Ultrasound images usually present low quality (low SNR)
- Images are corrupted by *speckle* noise (multiplicative)
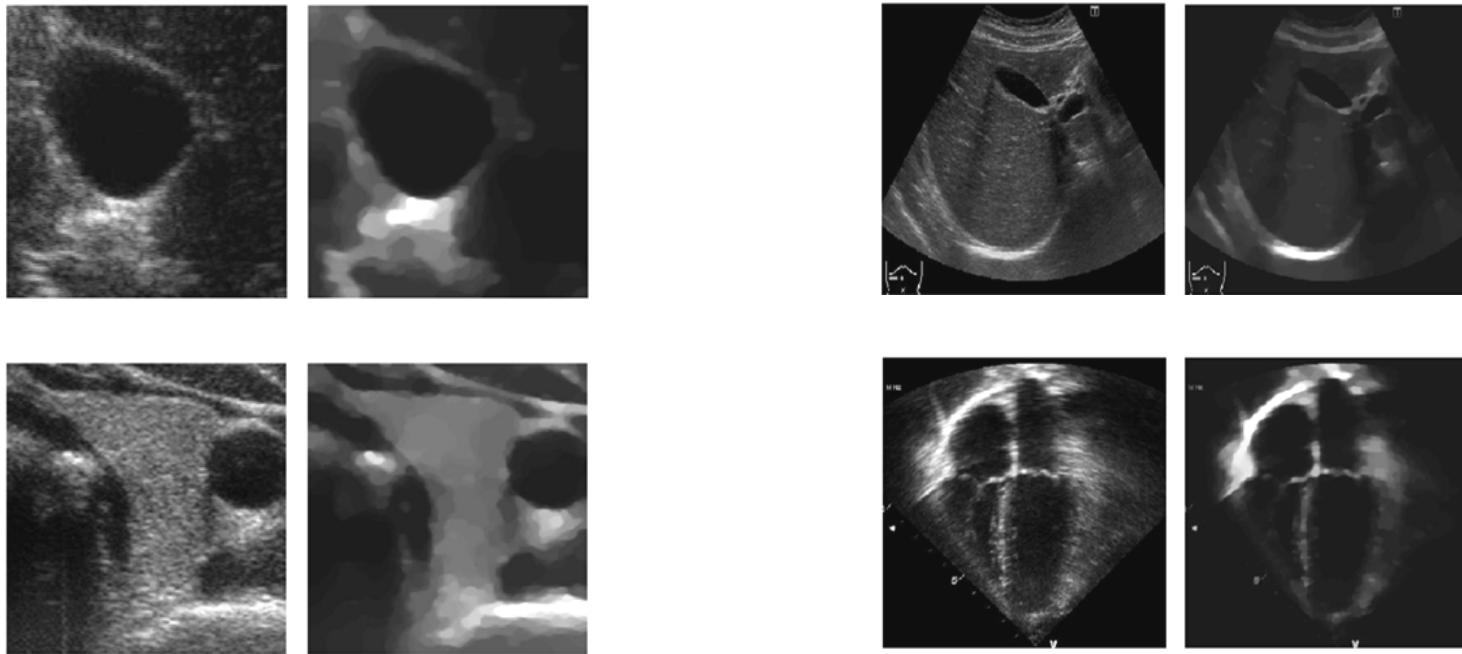
Processed by José Seabra (Biomedical PhD student)

Medical Information

Speckle Pattern (texture) contains relevant medical information
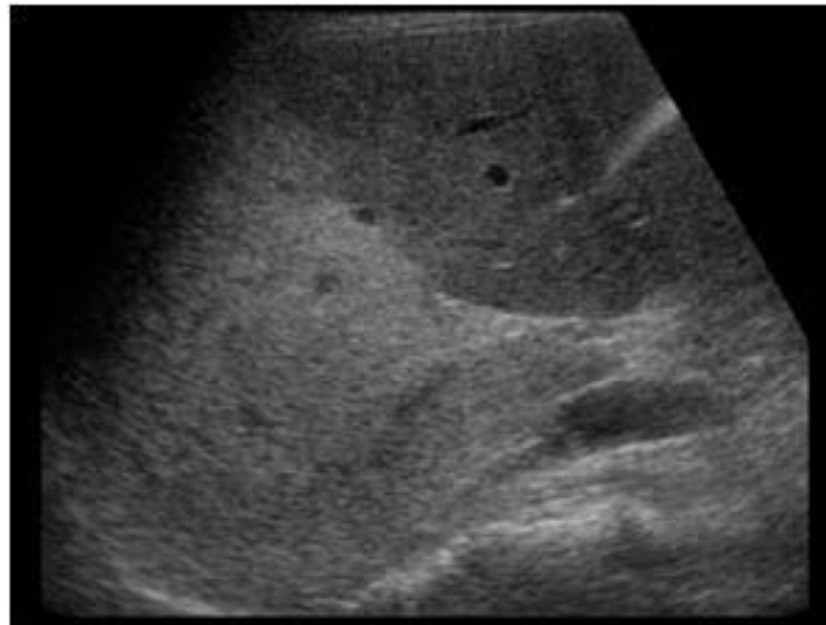
fatty Liver.

Image Decomposition

- Decompose the image in textural and anatomical/morphological components.

- Characterize the texture/"noise" (speckle).

- Associate the texture characteristics with the disease.

- Classification and Quantification for Detection (Diagnosis) and Quantification (Severity Assessment) of the disease.
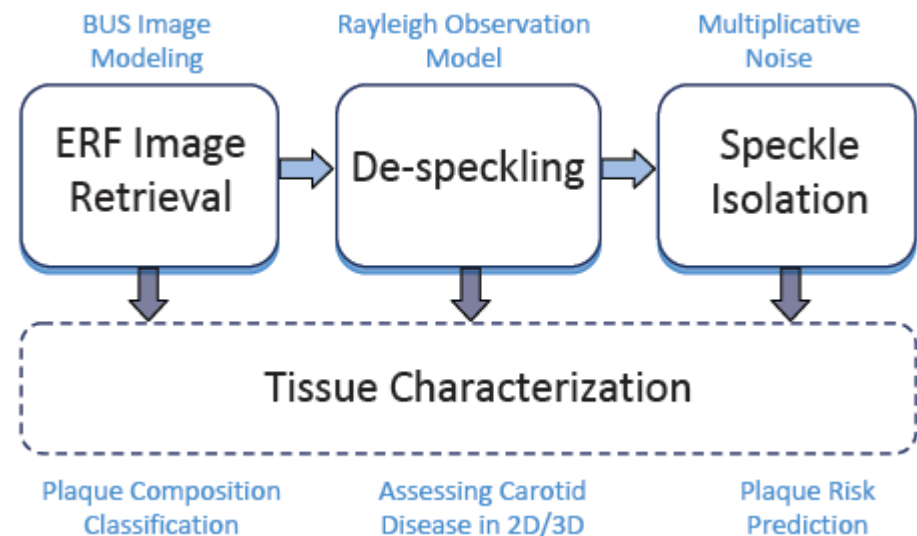
Decomposition Examples
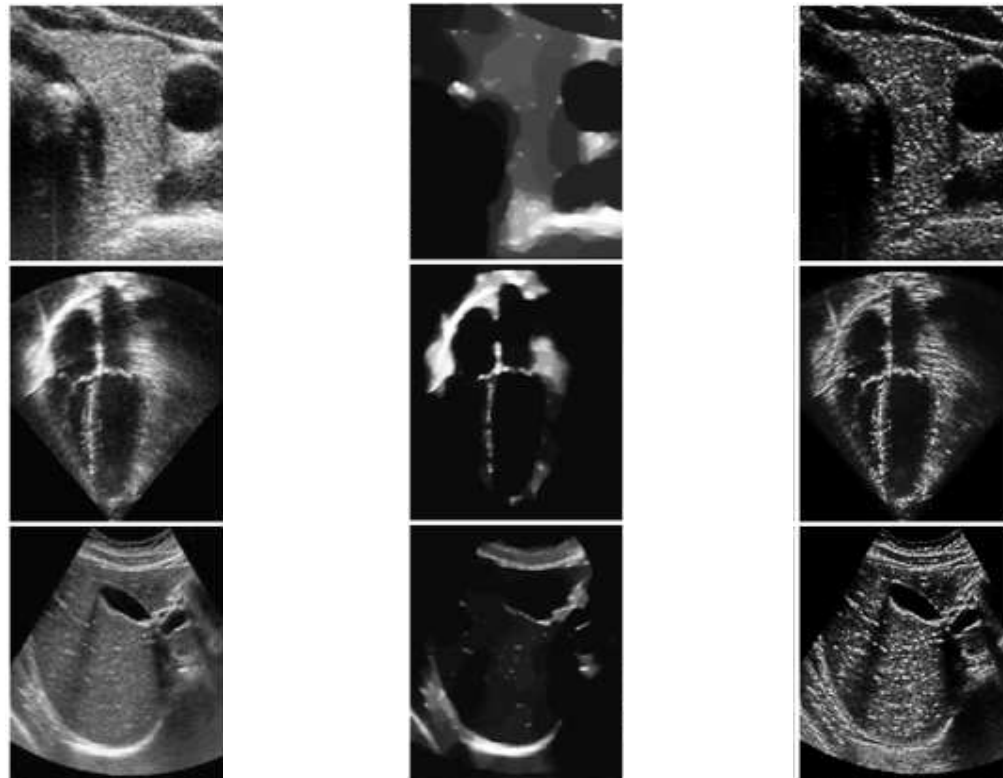
Seabra, J.C.; Ciompi, F.; Pujol, O.; Mauri, J.; Radeva, P.; Sanches, J. , "Rayleigh Mixture Model for Plaque Characterization in Intravascular Ultrasound," Biomedical Engineering, IEEE Transactions on , vol.58, no.5, pp.1314-1324, May 2011.

Speckle Analysis for Diagnostic Purposes

- **Liver Steatosis**
  - Ricardo Ribeiro (PhD Student)

- **Classification and Staging of Chronic Liver Disease from Multimodal Data**
  - Ricardo Ribeiro (PhD Student)

- **Carotid Atherosclerotic Plaques**
  - José Seabra (PhD)
  - David Afonso (PhD Student)
  - Manya Afonso (PhD, Post-Doc)
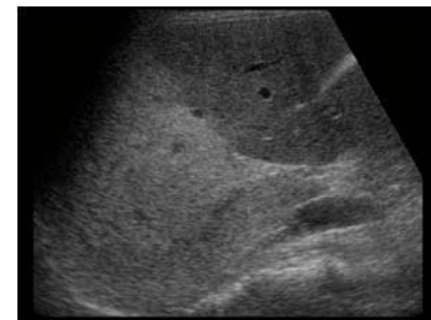
Liver (Steatosis and Cirrhosis)

- Diffuse Liver diseases such as Steatosis and Cirrhosis are mainly textural abnormalities of the hepatic parenchyma

- Today, the assessment is subjectively performed by visual inspection
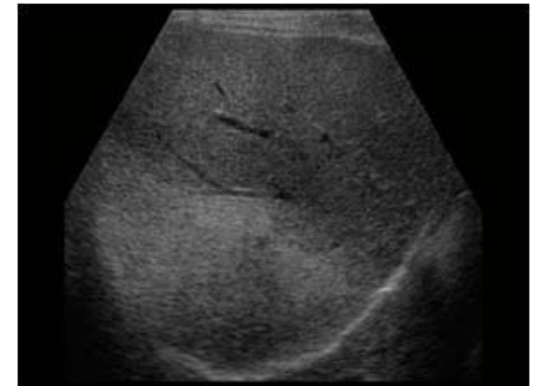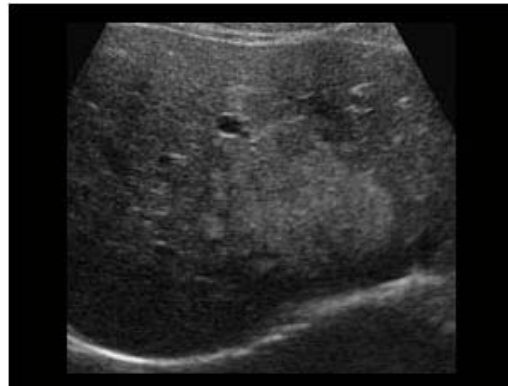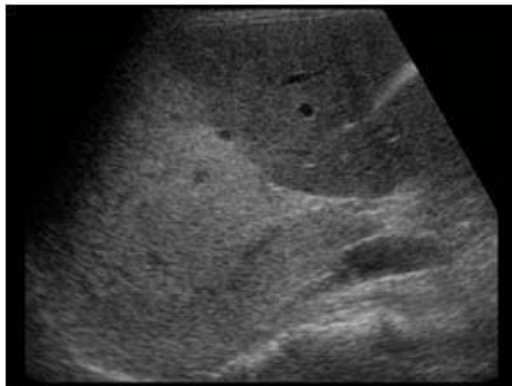
Steatosis

- Comparison with histological data
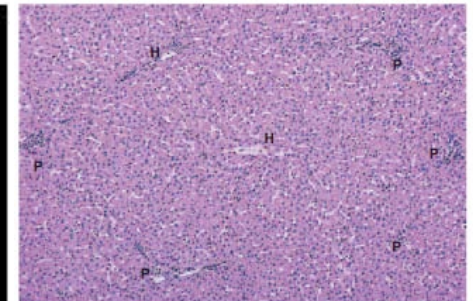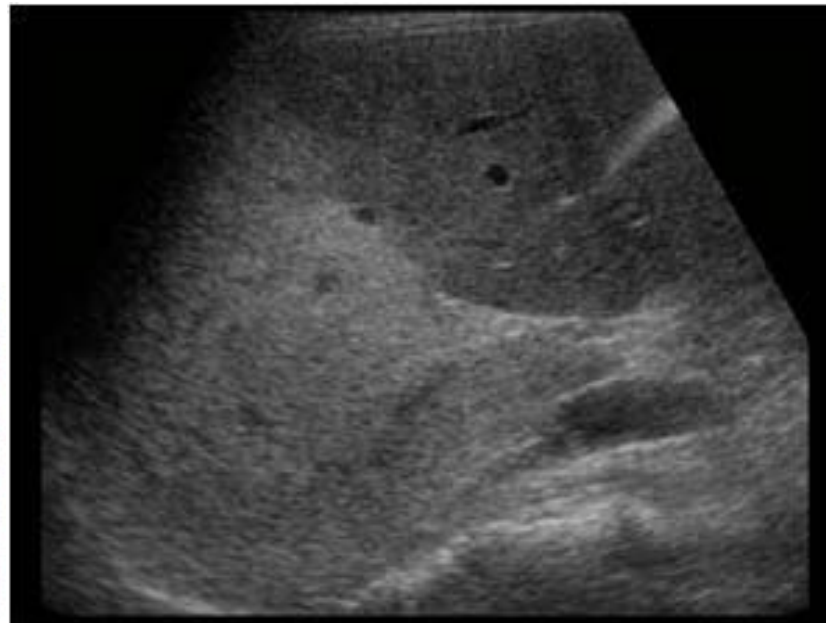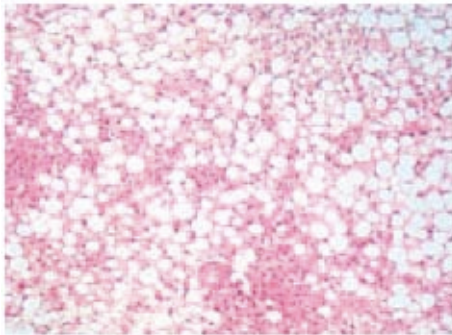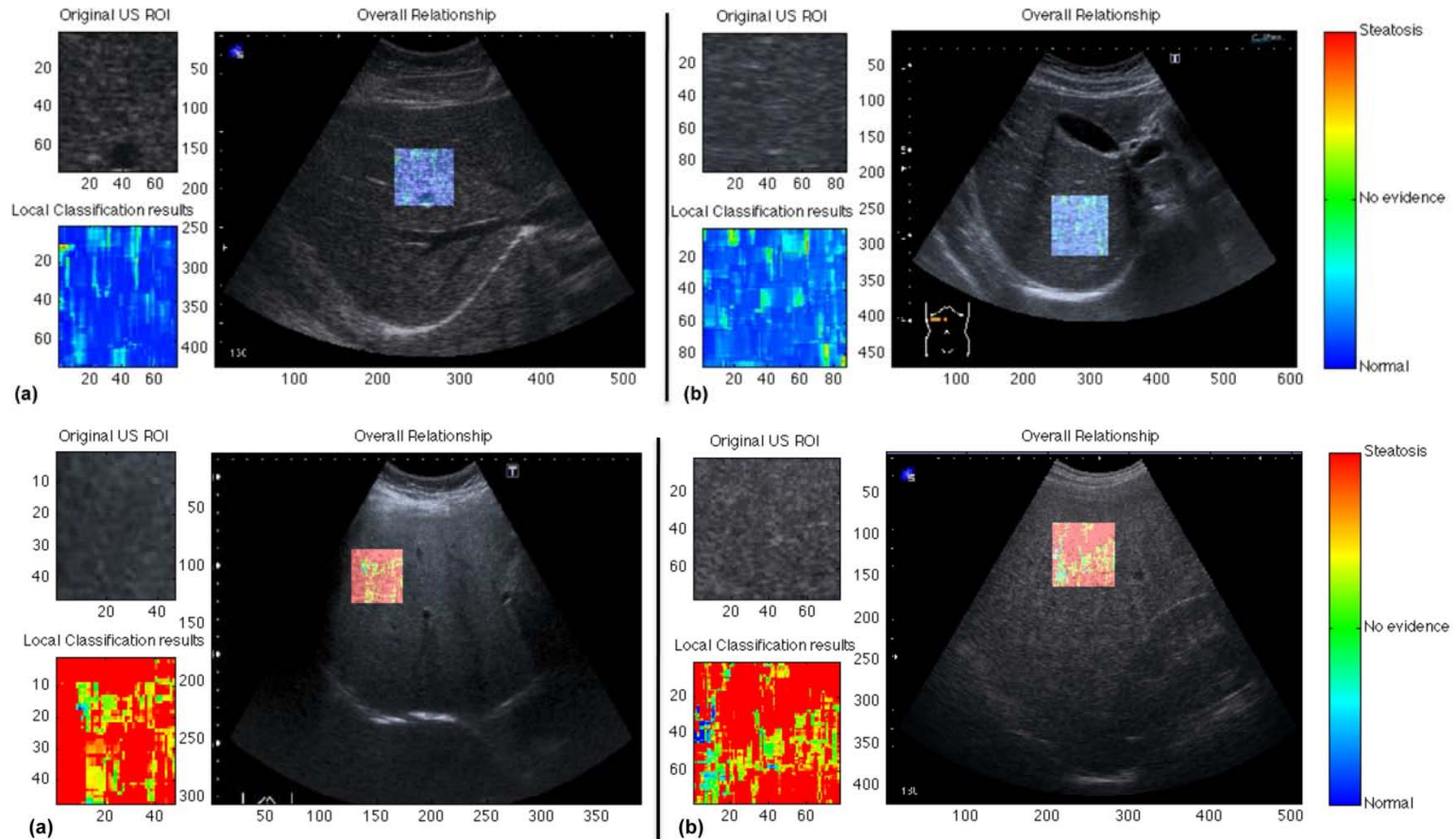
Liver Steatosis
Local Analysis

Classification and Staging of Chronic Liver Disease from Multimodal Data

Normal · chronic hepatitis · Cirrhosis compensated · decompensated
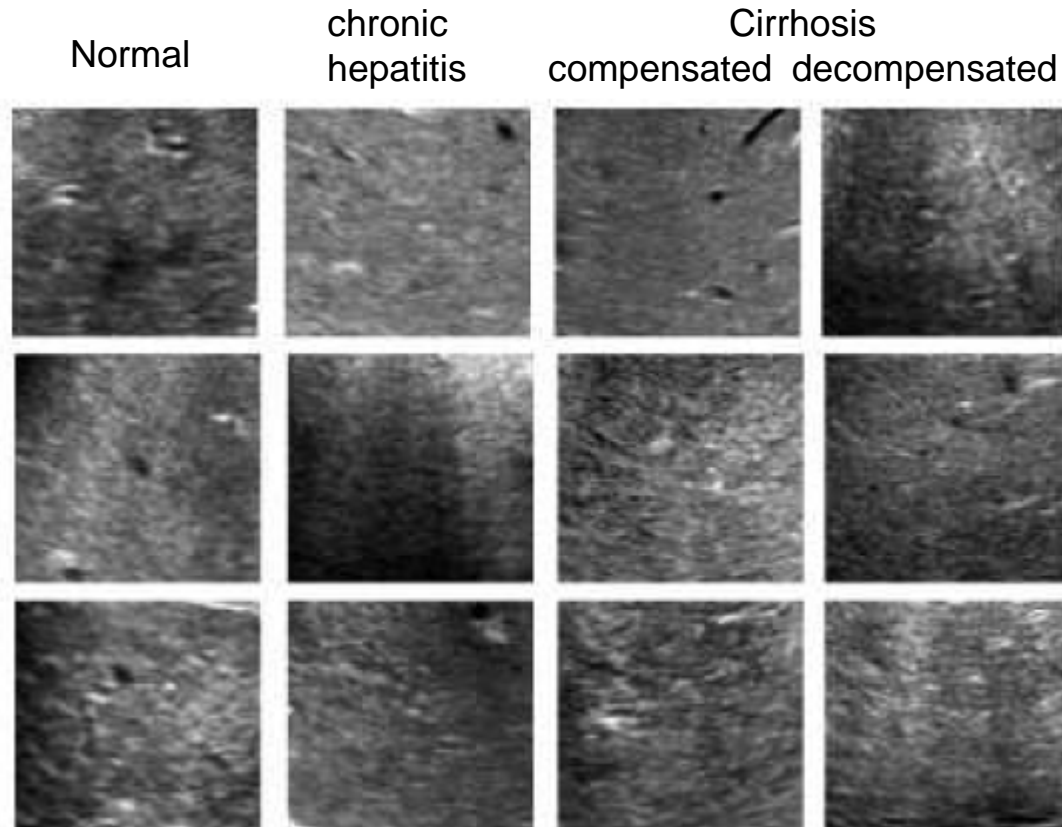
Clinical Based Classifier (CBC)
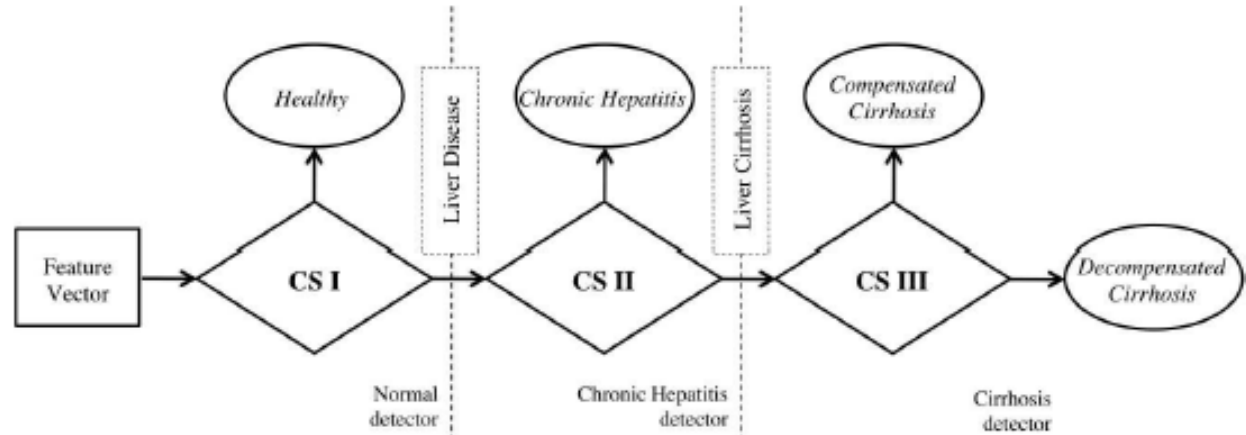
CS	FS	Class	Best Performance			
			DR (%)	OA (%)	J	Classifier
I	A	Normal	97.92	98.67	0.97	kNN k=1
		Pathologic	99.02			
	B	Normal	100.00	98.00	0.97	SVM$_{polynomial}$ d=1
		Pathologic	97.06			
II	A	CH	73.33	86.00	0.65	kNN k=1
		Cirrhosis	91.43			
	B	CH	70.00	80.39	0.55	SVM$_{polynomial}$ d=3
		Cirrhosis	84.72			
III	A	CC	97.14	91.67	0.84	Bayes
		DC	86.49			
	B	CC	88.57	90.27	0.80	Bayes
		DC	91.89			

Atherosclerotic Plaques
Carotid
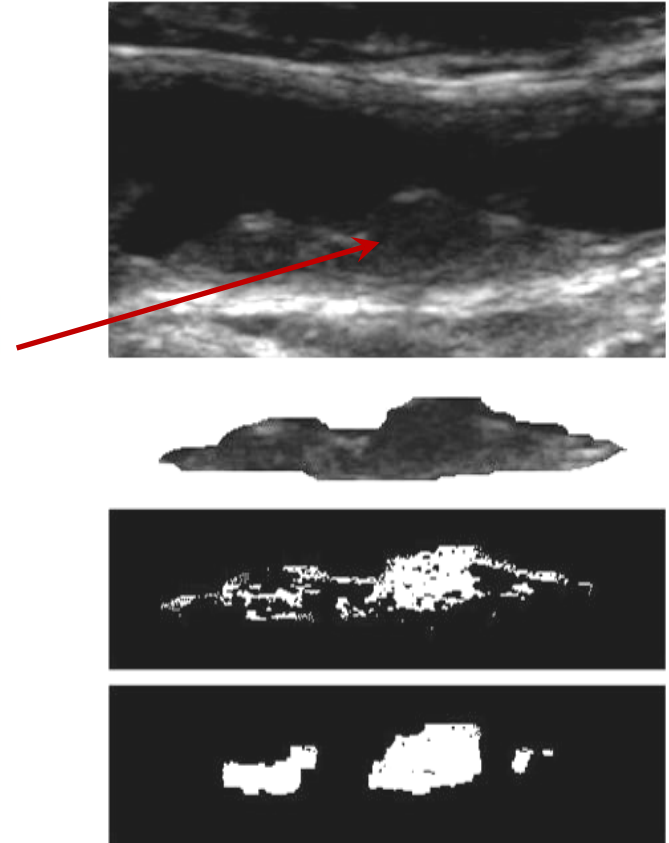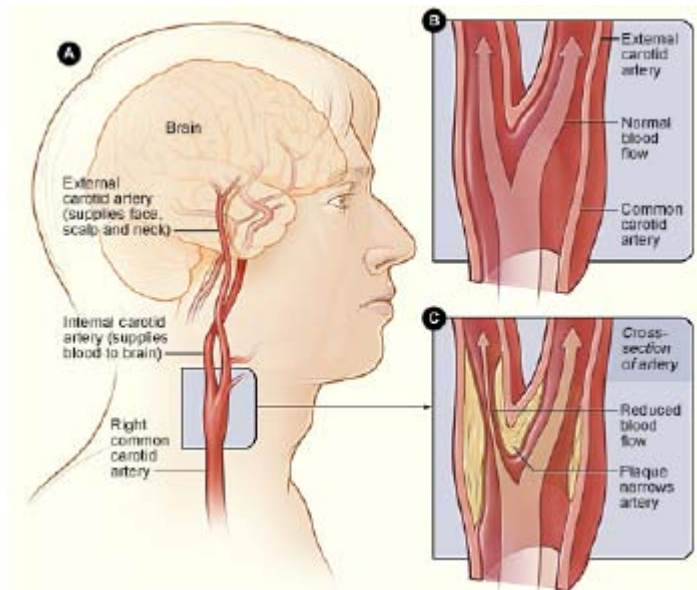
Tissue Characterization
from Intra Vascular US (IVUS)
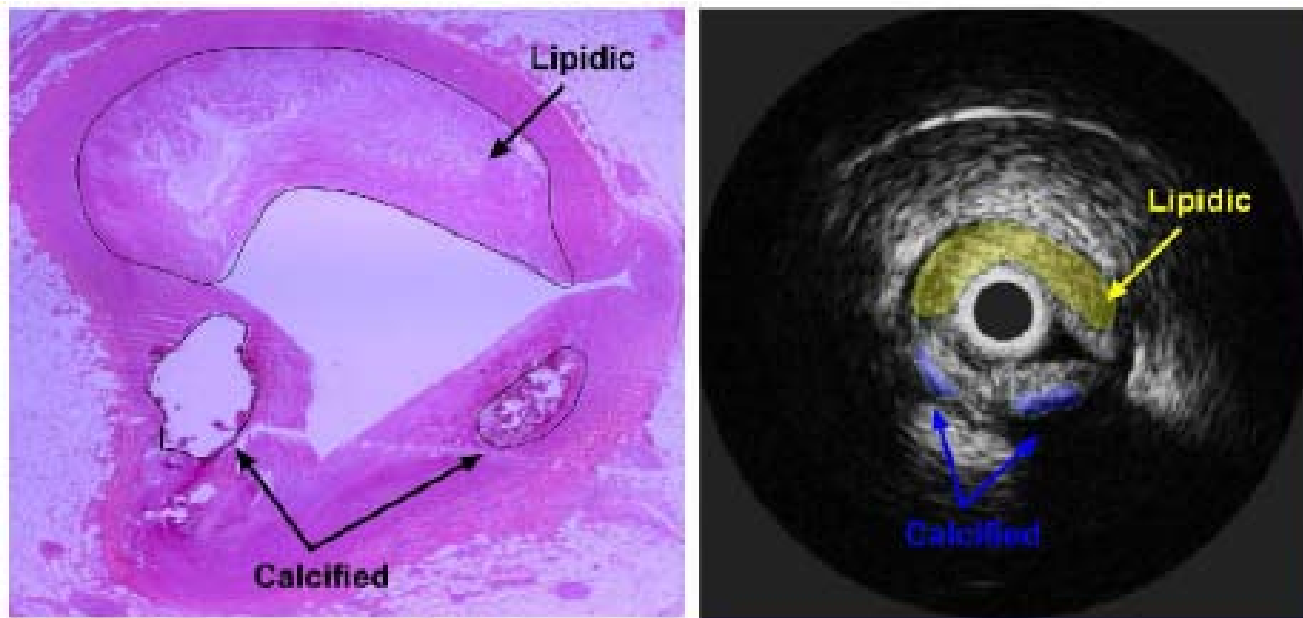
Collaboration with the **Centre de Visió per Computador,**
Universitat Autònoma de Barcelona, Profª Petia Radeva
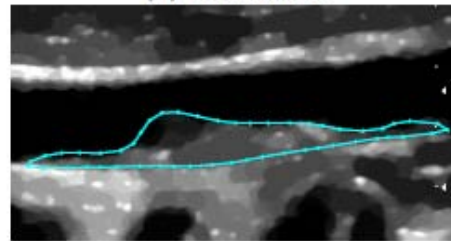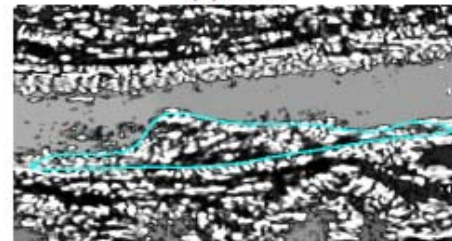
Plaque IVUS

Decomposition
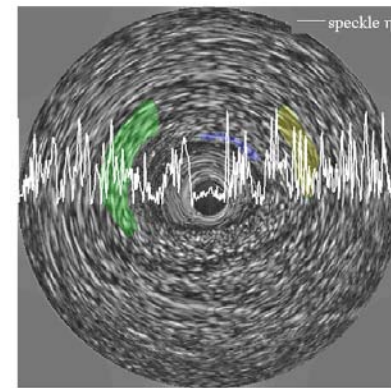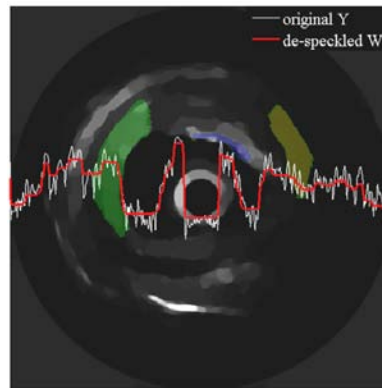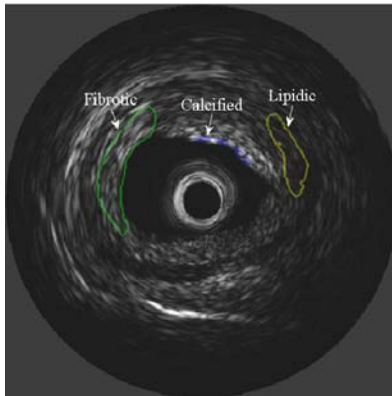
Classification
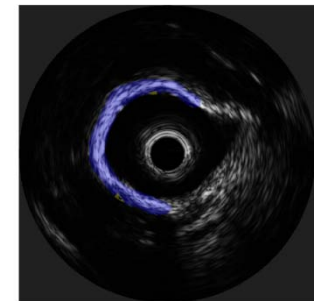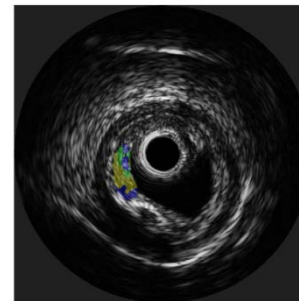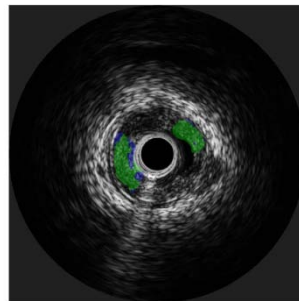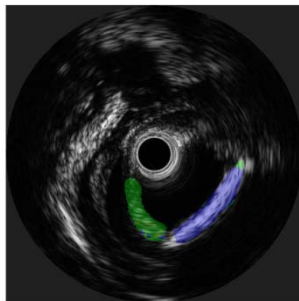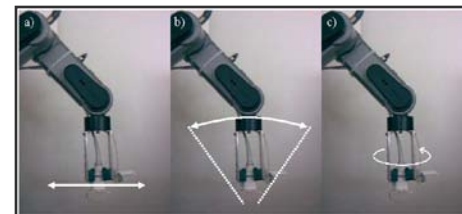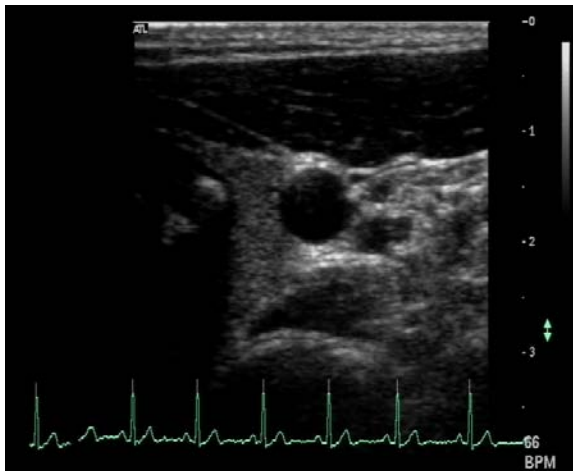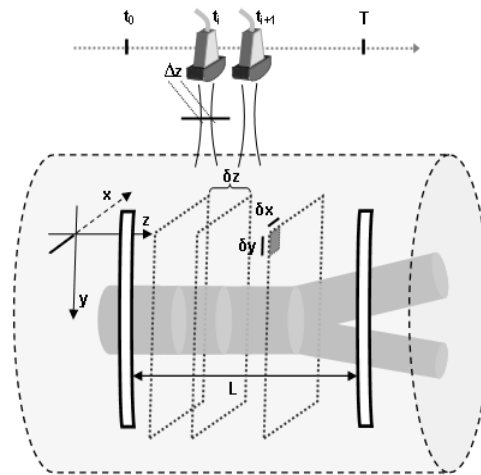
Plaque B-Mode
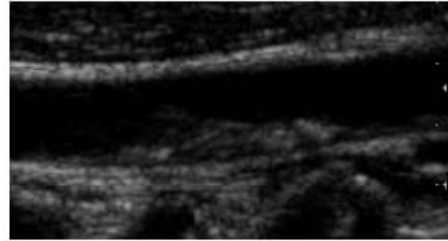
(a) original
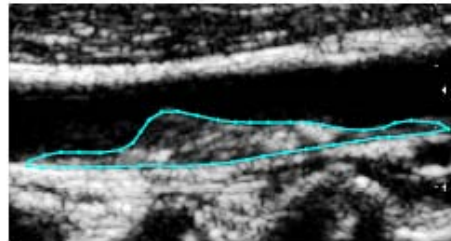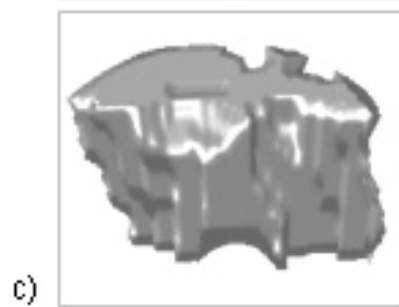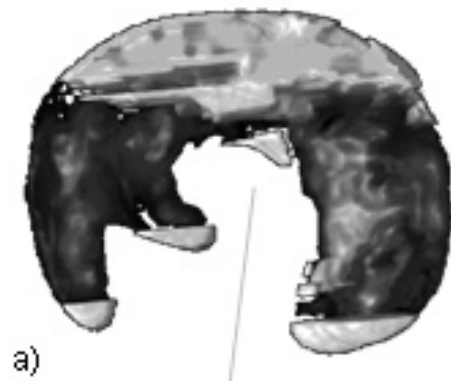
(b) normalized
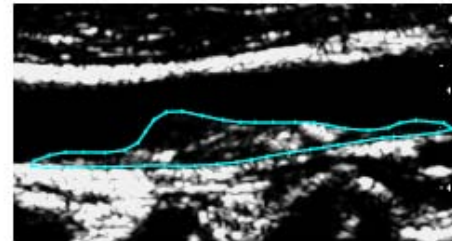
(c) ERF

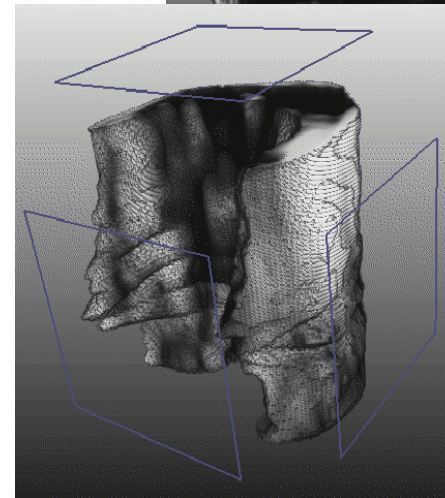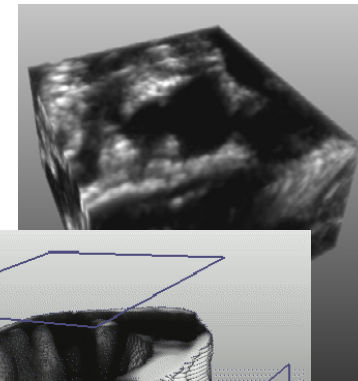(d) speckle-free

(e) speckle

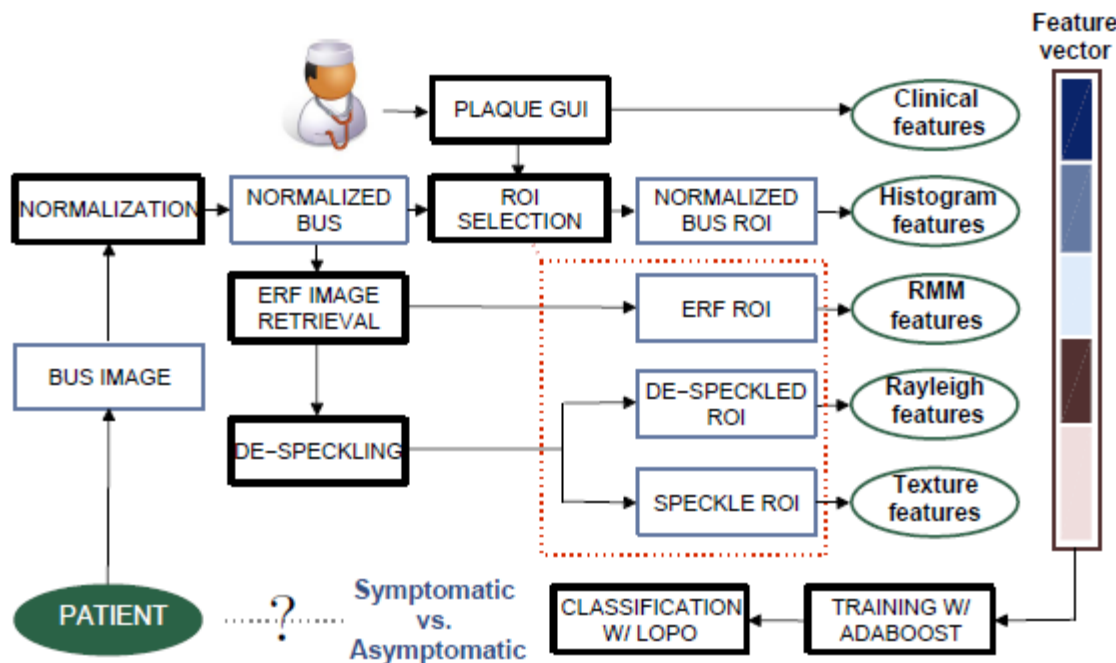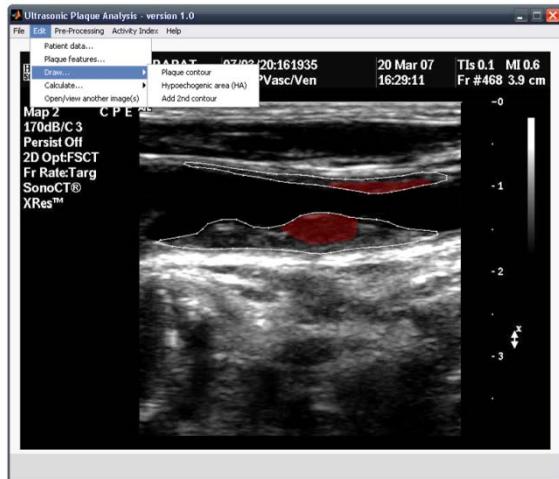# 3D Generalization
US Acquisition

- Freehand
- Mechanical

3D Diagnosis

Global and local analysis

a)

b)

c)

Total Volume	1058cm^3
Hypoechogenic region	565cm^3
Ratio	0.53

Enhanced Activity Index (EAI)
Architecture

Enhanced Activity Index (EAI)
Prototype

Computer Aided Diagnosis
AtherosRisk™

THANKS