Medical Imaging Projects

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Outline

- Medical Informatics
- Imaging Modalities
  - Computed Tomography
- Medical Image Processing
- Project 1: Content-based Image Retrieval for Medical Applications
- Project 2: Texture-based visualization of soft tissues

What is Medical Informatics?

Simplistic definition:

Medical informatics is the application of computers, communications and information technology and systems to all fields of medicine - medical care, medical education and medical research.

MF Collen, MEDINFO '80, Tokyo

What is Medical Informatics?

Medical Informatics is the branch of science concerned with the use of computers and communication technology to acquire, store, analyze, communicate, and display medical information and knowledge to facilitate understanding and improve the accuracy, timeliness, and reliability of decision-making.

Warner, Sorenson and Bouhaddou, Knowledge Engineering in Health Informatics, 1997

Subdomains of Medical Informatics (by Wikipedia)

- **imaging informatics**

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Imaging Informatics

The Imaging Informatics Section is the computing arm of the Department of Radiology. As such, we have three primary missions:

1. We provide technical and operational support to the Northwestern Memorial Hospital (NMH) Picture Archiving and Communication System (PACS) and the NMH PACS team. We also provide research imaging services to the Northwestern PACS user community.
2. We support the computing needs of the faculty radiologists, their staff and the residents. This includes desktop computer and network support. We also provide FTP, e-mail, internal and external Web servers, and research DICOM image archive services.
3. We operate the Imaging Informatics research laboratory. The laboratory is a 4000 sqare foot facility, fully equipped for imaging informatics research. We operate a large UNIX server as well as several Windows 2000 and Windows NT servers. We also operate two PACS test environments that emulate the c

What is Medical Imaging?

The study of *medical imaging* is concerned with the interaction of all forms of radiation with tissue

and

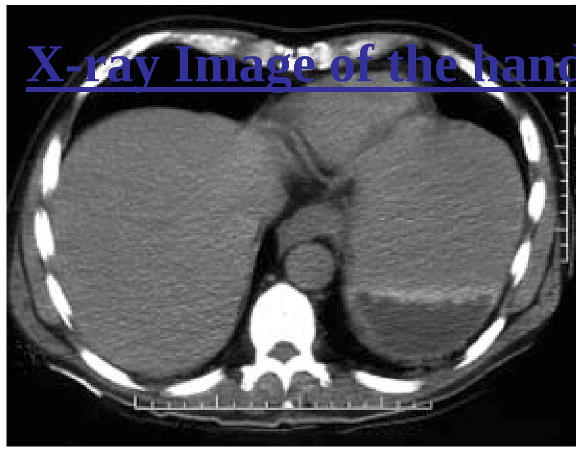
the development of appropriate technology to extract clinically useful information (usually displayed in an image format) from observation of this technology.

Sources of Images:

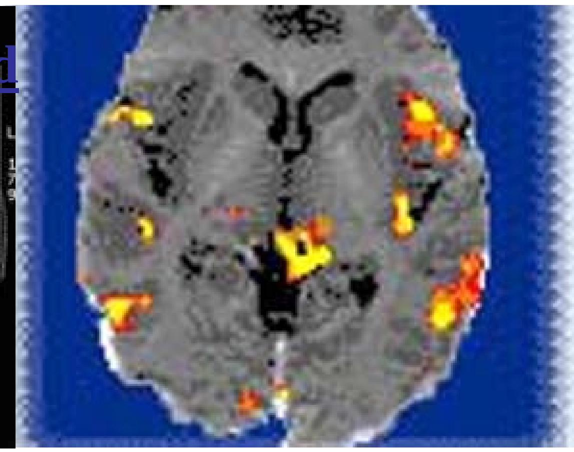
- Structural/anatomical information (CT, MRI, US, VH) - within each elemental volume, tissue-differentiating properties are measured.
- Information about function (PET, SPECT, fMRI).

Examples of Medical Images

X-ray Image of the hand



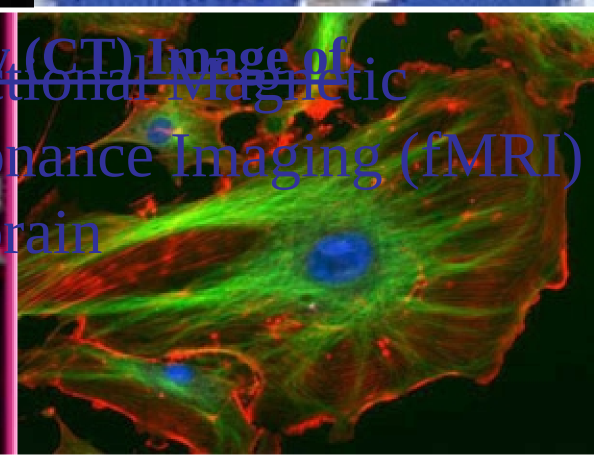
Computed Tomography (CT) Image of plane through liver and stomach



Functional Magnetic Resonance Imaging (fMRI) of the brain

Ultrasound image of a woman's abdomen

Single Photon Computed Tomography image of the heart



Fluorescence Microscopy image of living tissue culture cells.

Computed Tomography (CT)

- G. Hounsfield (computer expert) and A.M. Cormack (physicist) (Nobel Prize in Medicine in 1979)

- CT overcomes limitations of plain radiography

- CT doesn’t superimpose structures (like X-ray)

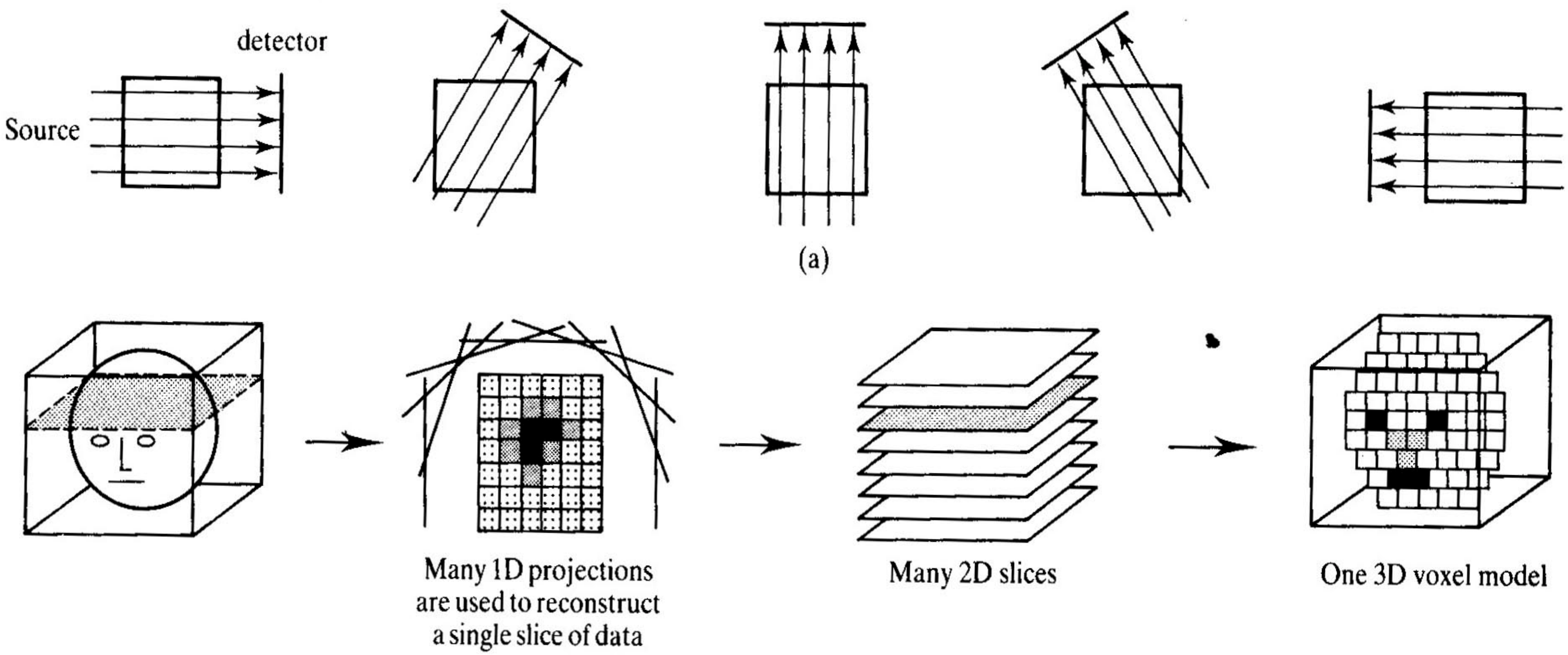
- CT is an imaging based on a mathematical formalism that states that if an object is viewed from a number of different angles than a cross-sectional image of it can be computed (*reconstructed*)

CT Data

Stages of construction of a voxel dataset from CT data

(a) CT data capture works by taking many one dimensional projections through a slice (scanning)

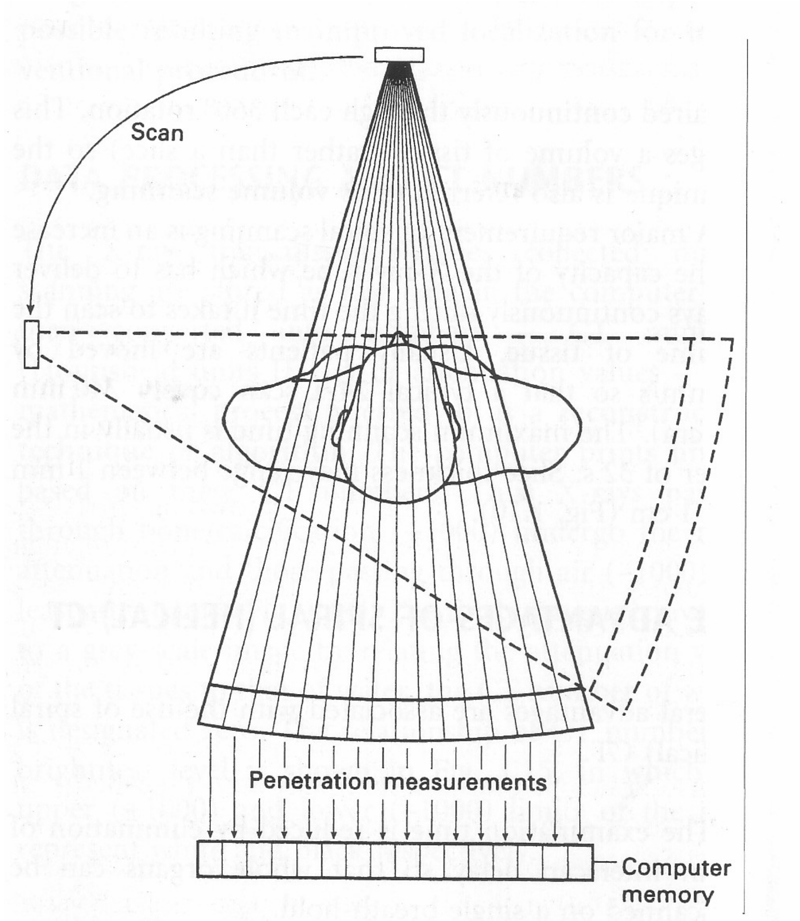
(b) CT reconstruction pipeline



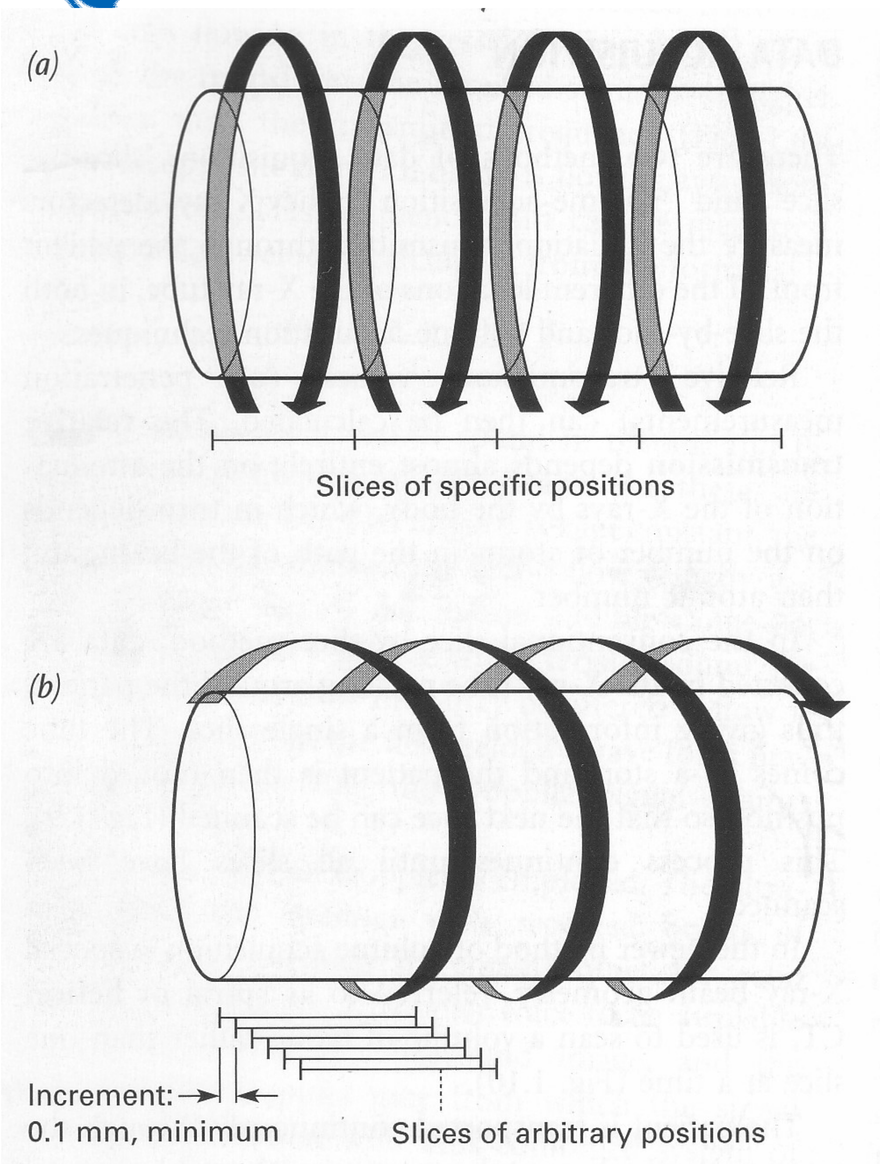
CT – Data Acquisition

Slice-by-slice acquisition
- X-ray tube is rotating around patient to acquire a slice
- patient is moved to acquire the next slice

Volume acquisition
- X-ray tube is moving continuously along a *spiral (helical)* path and the data is acquired continuously



CT – Data Acquisition



(a) slice-by-slice scanning

(b) Spiral (volume) scanning

CT – SPIRAL SCANNING

- a patient is moved 10mm/s (24cm / single scan)
- slice thickness: 1mm-1cm
- faster than slice-by-slice CT
- no shifting of anatomical structures
- slice can be reconstructed with an arbitrary orientation with (a single breath) volume

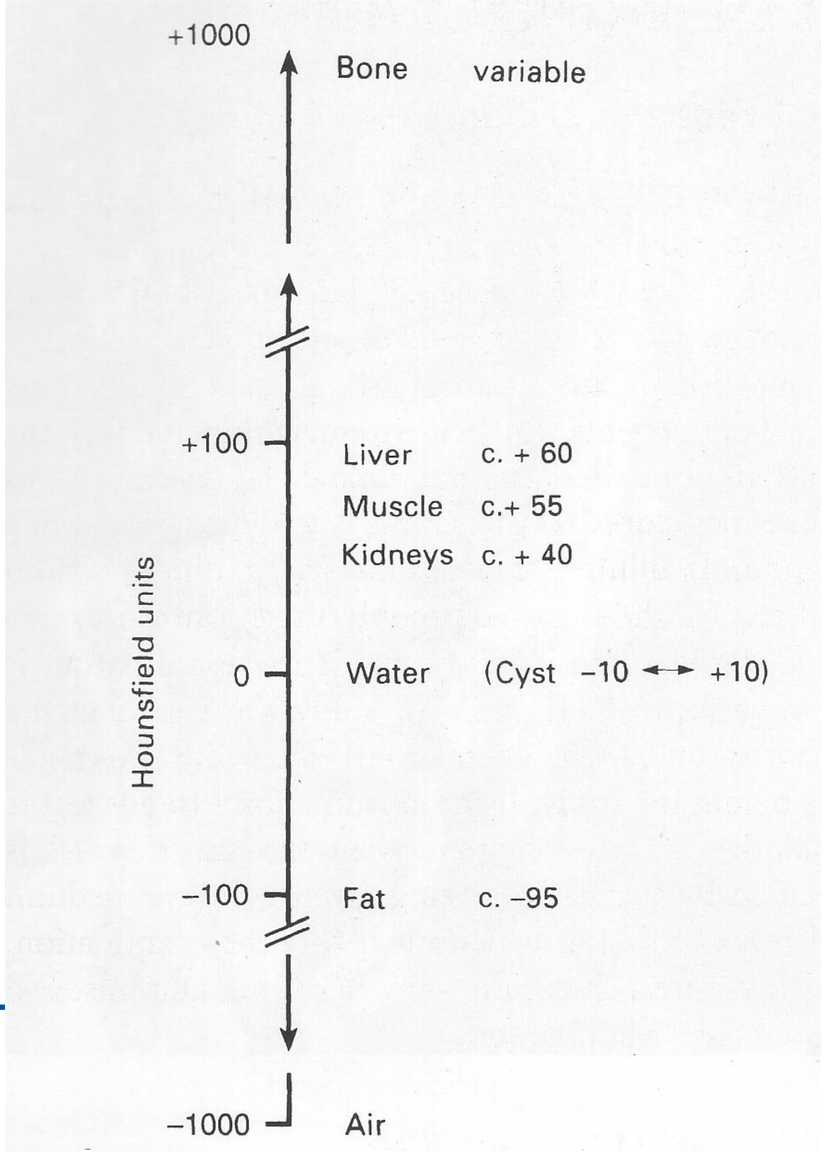
CT multi-slice systems:

- parallel system of detectors
- 4/8/16 slices at a time
- generates a large data of thin slices
- better spatial resolution (→ better reconstruction)

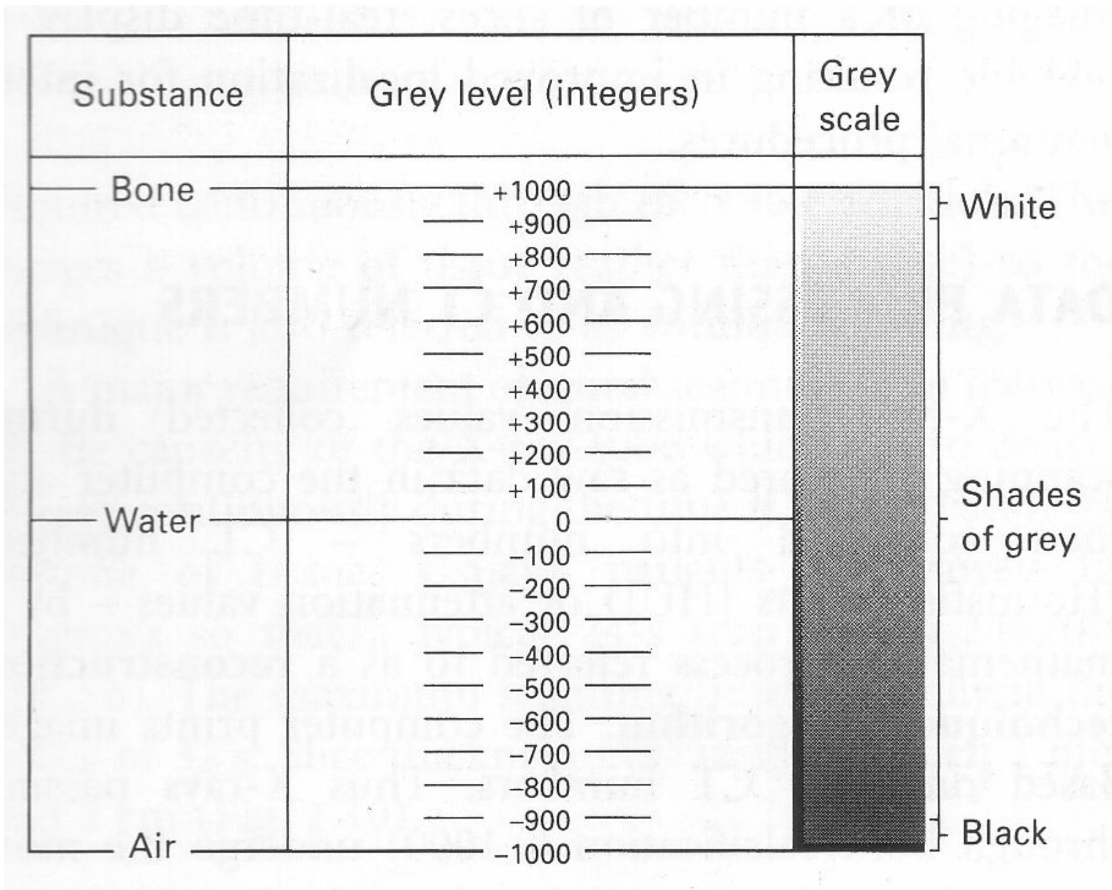
CT - DATA PROCESSING

CT numbers (Hounsfield units) HU:

- computed via reconstruction algorithm (~tissue density/ X-ray absorption)
- most attenuation (bone)
- least attenuation (air)
- blood/calcium increases tissue density



CT - DATA PROCESSING



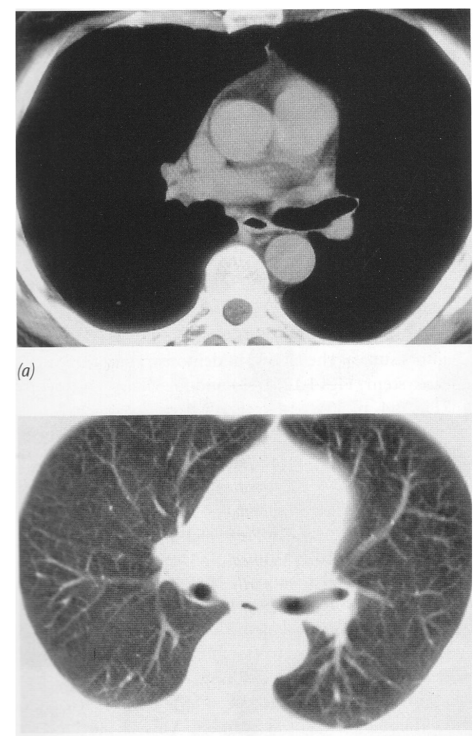
Relationship between CT numbers and brightness level

CT - IMAGE DISPLAY

Human eye can perceive only a limited range gray-scale values

Thoracic image:
a) width 400HU/level 40HU (no lung detail is seen)

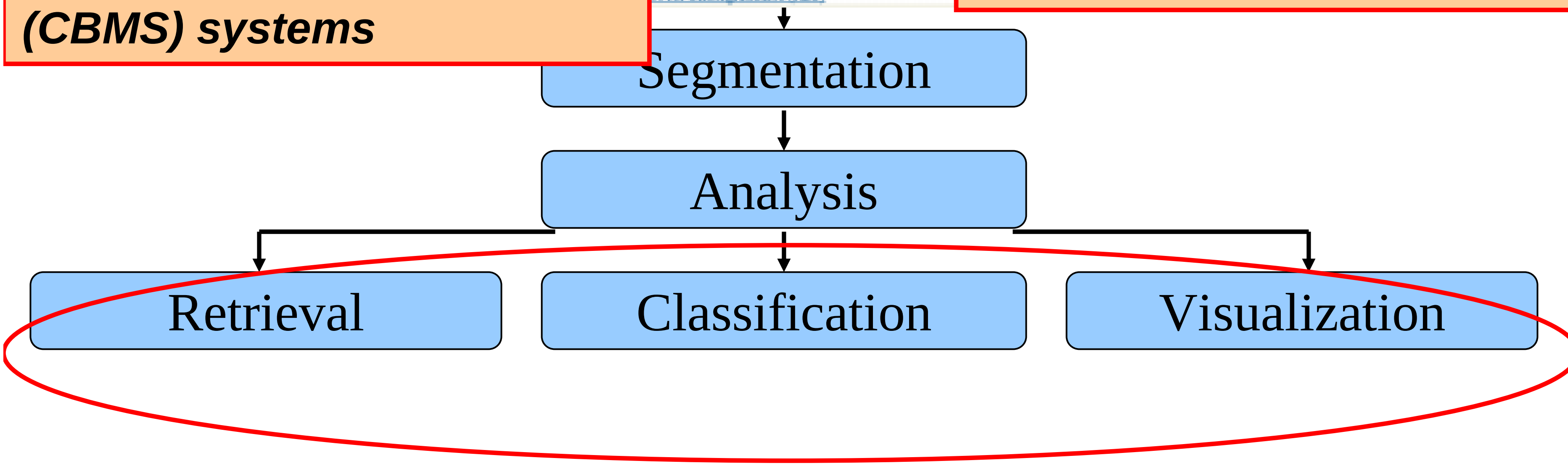
b) width 1000HU/level –700HU (lung detail is well seen; bone and soft tissue detail is lost)



(MI)@ CTI

***Project 1:** content-based medical image retrieval (CBMS) systems*

***Project 2:** texture-based visualization of soft tissues*



<u>Project 1:</u> Content-based medical image retrieval (CBMS) systems

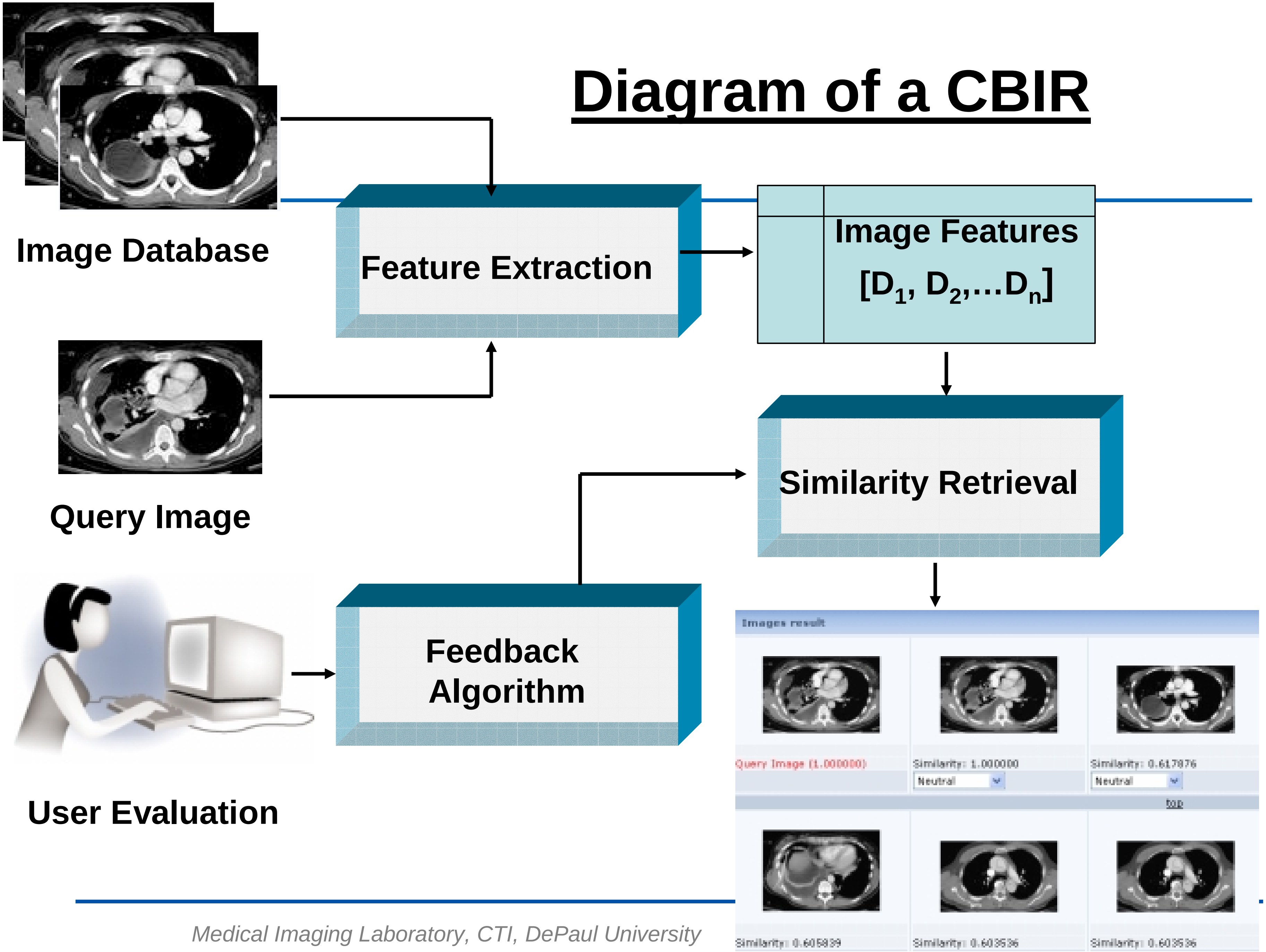
<u>Definition of Content-based Image Retrieval:</u>

Content-based image retrieval is a technique for retrieving images on the basis of automatically derived image features such as texture and shape.

<u>Applications of Content-based Image Retrieval:</u>

- Teaching
- Research
- Diagnosis
- PACS and Electronic Patient Records

Diagram of a CBIR

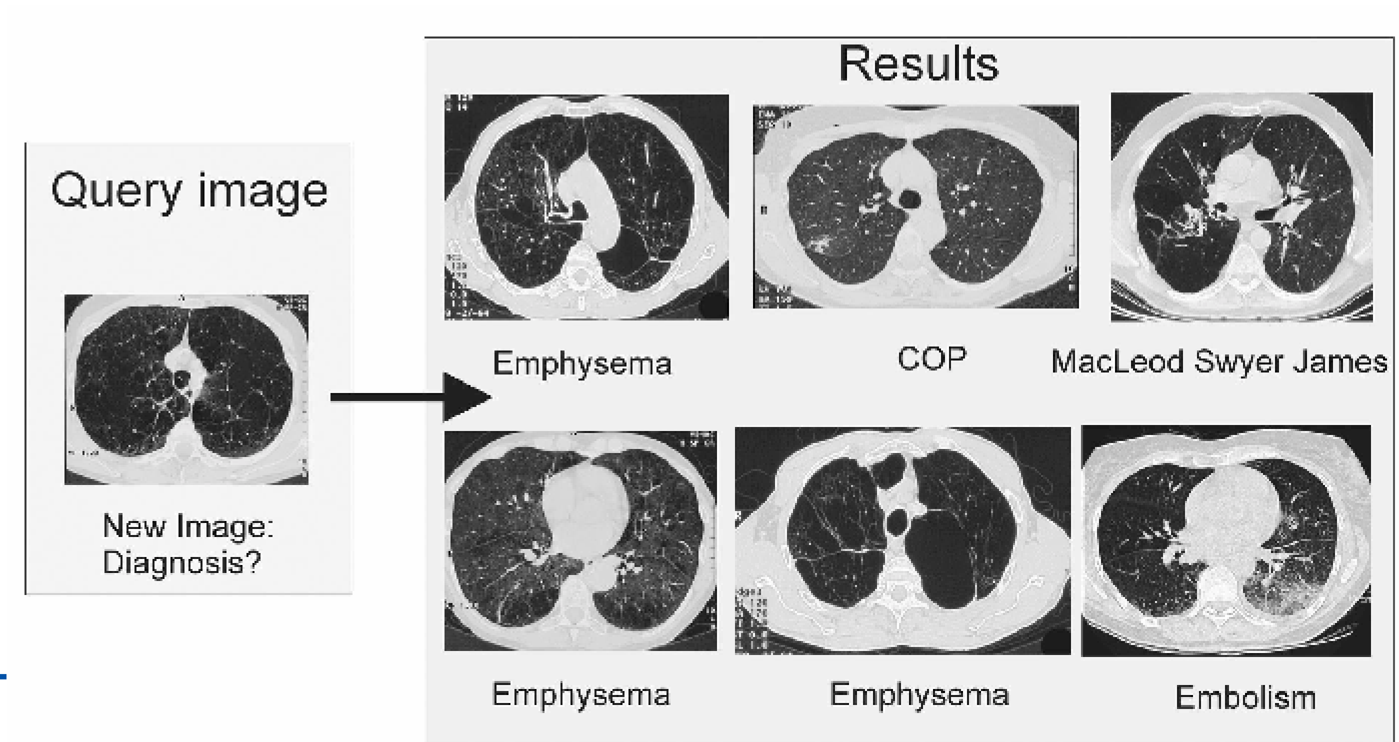


Medical Imaging Laboratory, CTI, DePaul University

http://viper.unige.ch/~muellerh/demoCLEFmed/index.php

CBIR as a Diagnosis Aid

Figure 1. Content-based image retrieval as a diagnostic aid with use of medGift and the casimage database. The query image (left) shows emphysematous lesions with multiple confluent centrilobular and paraseptal areas of low attenuation without visible walls. The search results show six images, including five cases of emphysema (right), with each image accompanied by a link to the complete case description. One image demonstrates unilateral emphysema (MacLeod [Swyer-James] syndrome), and two images show a small area of consolidation in the pulmonary parenchyma (cryptogenic organized pneumonia *[COP]* and pulmonary embolism). The typical pattern of pulmonary parenchyma destruction seen on these five images strongly suggests the diagnosis of emphysema for the query image.



CBIR as a Teaching Tool

An image retrieval system will allow students/teachers to browse available data themselves in an easy and straightforward fashion by clicking on “show me similar images”.

Advantages:

- stimulate self-learning and a comparison of similar cases
- find optimal cases for teaching

Teaching files:

- Casimage: http://www.casimage.com
- myPACS: http://www.mypacs.net

CBIR as a Research Tool

Image retrieval systems can be used:

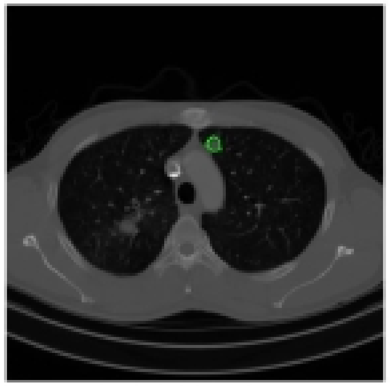
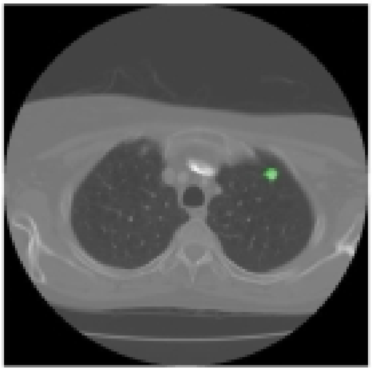
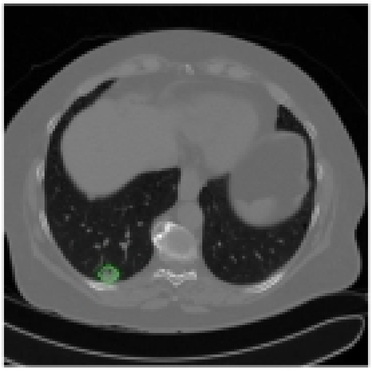
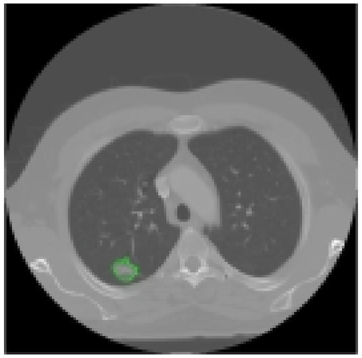
- to complement text-based retrieval methods
- for visual knowledge management whereby the images and associated textual data can be analyzed together
    - multimedia data mining can be applied to learn the unknown links between visual features and diagnosis or other patient information
- for quality control to find images that might have been misclassified

CBIR Application to Lung Image Retrieval

- Lung Imaging Database Resource for Imaging Research (30 cases)
  http://imaging.cancer.gov/programsandresources/InformationSystems/LIDC/page7

- Manual choice of one or several layers (representative)
- Marking of regions that describe the disease best
- Search for similar cases, the MD has then to decide on the diagnosis:
  - Content-based search retrieval
  - Textual retrieval
  - Combination of textual and image-based retrieval

CBIR Applications to Lung Image Retrieval

Radiologist Ratings:

SeriesInstanceUID	noduleID	nodule_no	calcification	internalStructure	lobulation	malignancy	margin	sphericity	spiculation	subtlety	texture
1.3.6.1.4.1.9328.50.3.272	2593	1	6	1	5	3	2	3	5	3	3
1.3.6.1.4.1.9328.50.3.272	4009	2	6	1	5	1	2	5	4	2	1
1.3.6.1.4.1.9328.50.3.378	4064	3	6	1	5	2	4	2	5	4	5
1.3.6.1.4.1.9328.50.3.648	001	4	6	1	4	5	3	2	1	5	4

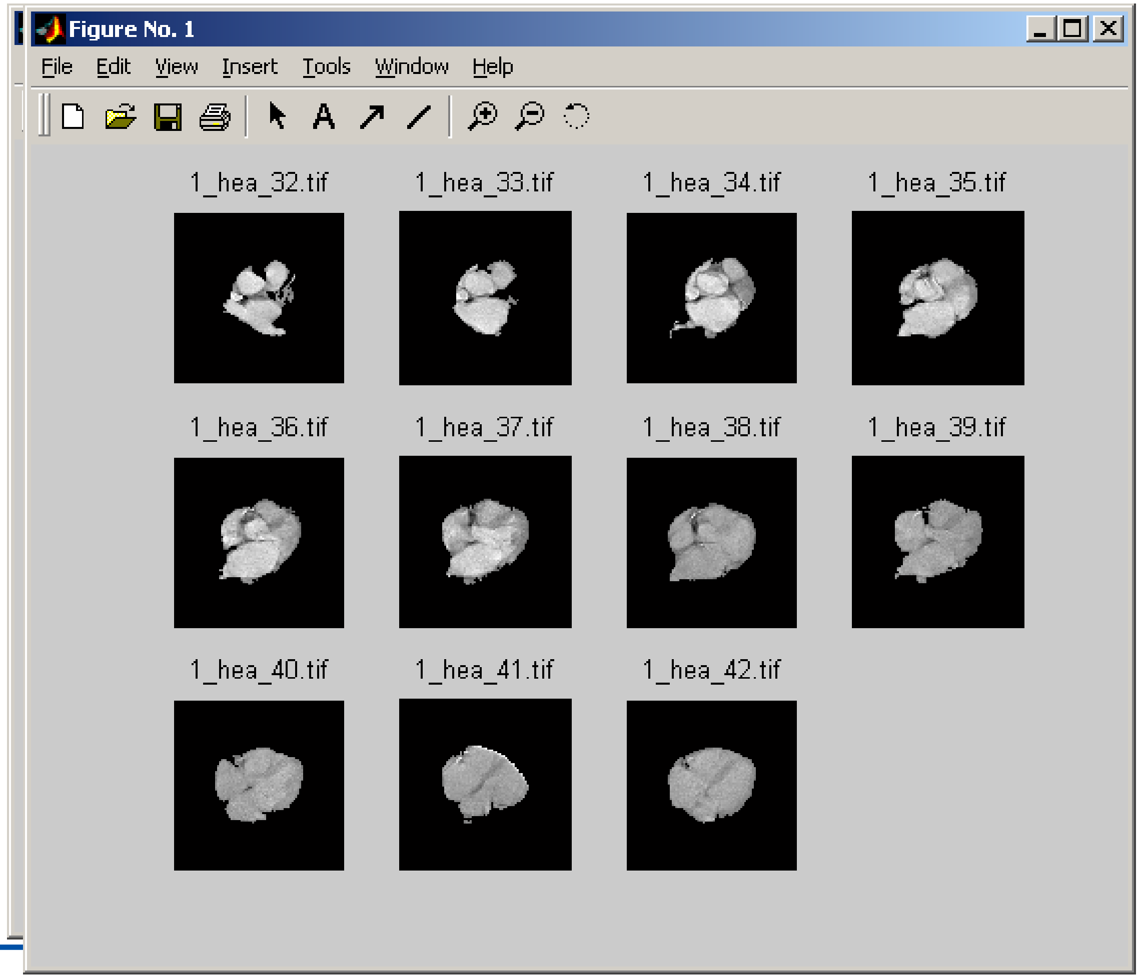
Image Features:

- local and global texture and shape features

CBIR Applications for Anatomical Structures Retrieval

Database of 344 CT images from 2 patients:

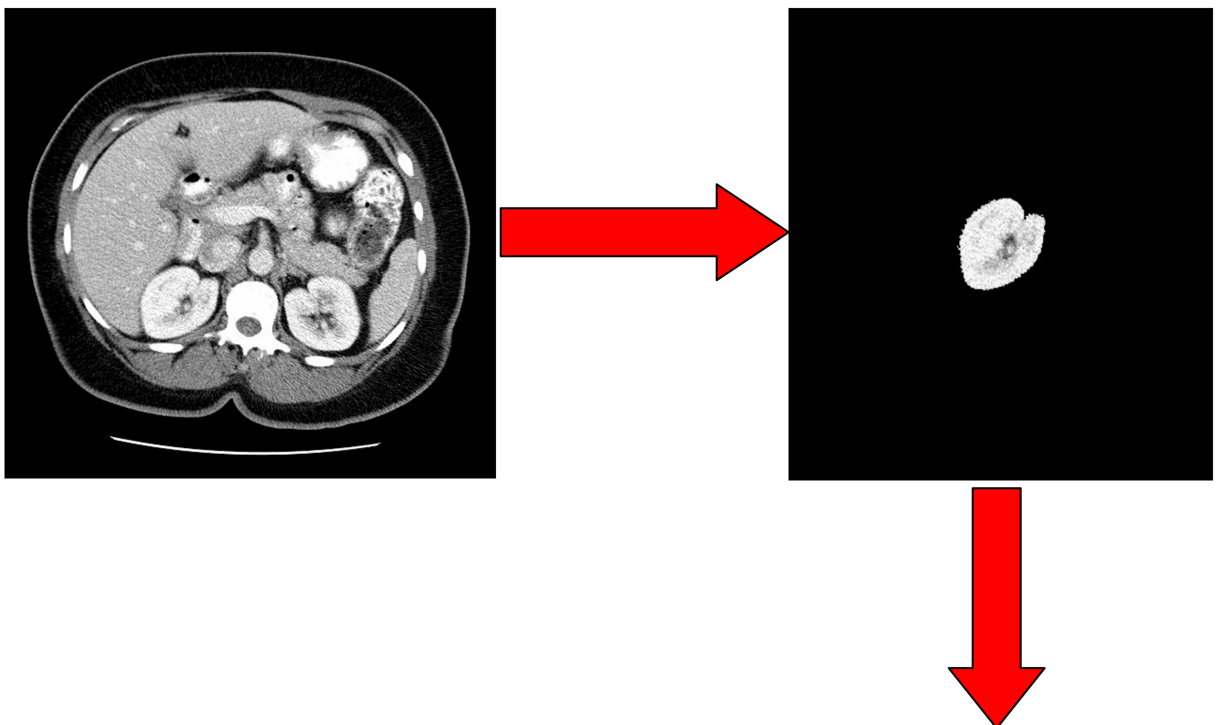
- Backbone
- Heart
- Spleen
- Liver
- Kidneys



CBIR Applications for Anatomical Structures Retrieval

Retrieval based on texture information:

- Statistical Features

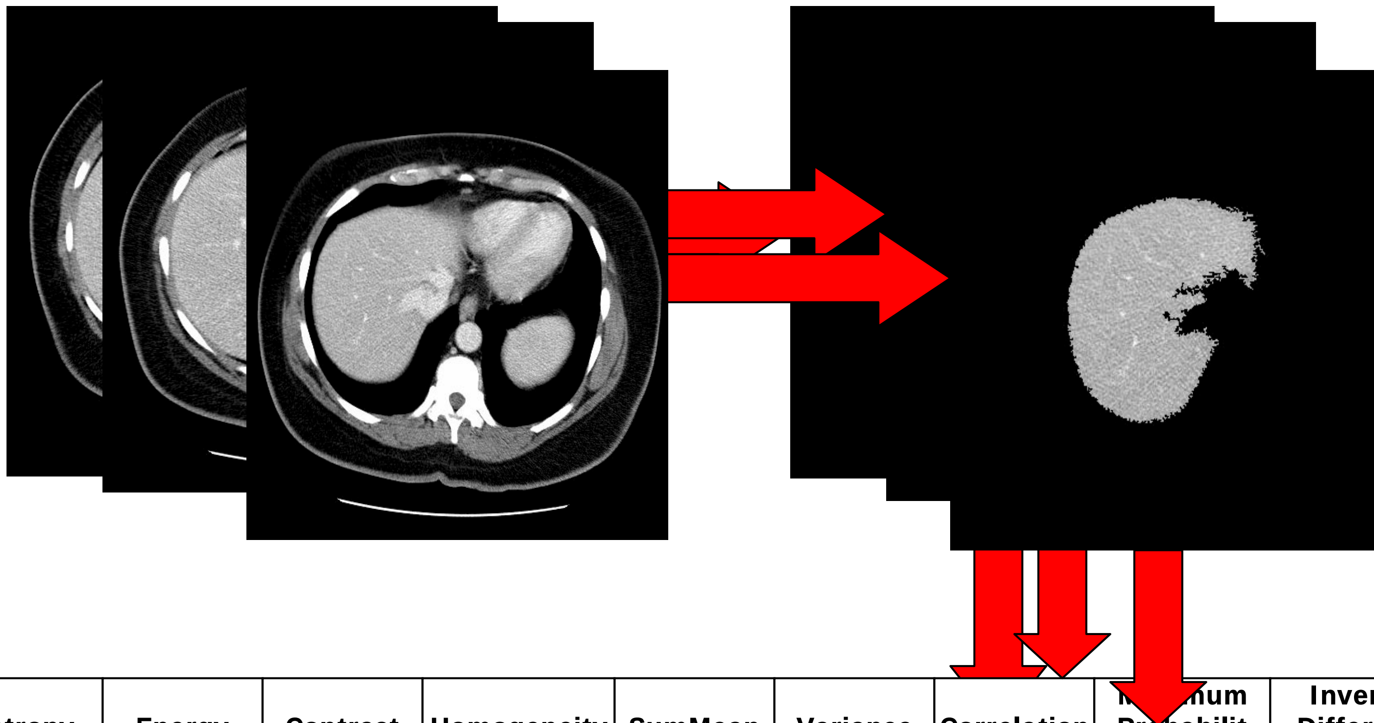


Entropy	Energy	Contrast	Homogeneity	SumMean	Variance	Correlation	Maximum Probability	Inverse Difference Moment	Cluster Tendency
3.38482	.055998	3.49784	.5577785	14.278469	3.737737	.1436305	.1250245	.437988	11.453111

CBIR Applications for Anatomical Structures Retrieval

Retrieval based on texture information:

- Statistical Features



Entropy	Energy	Contrast	Homogeneity	SumMean	Variance	Correlation	Maximum Probability	Inverse Difference Moment	Cluster Tendency
2.72509	.091388	1.618982	.6208175	11.755226	0.912752	.123976	.1742075	.506894	2.032082

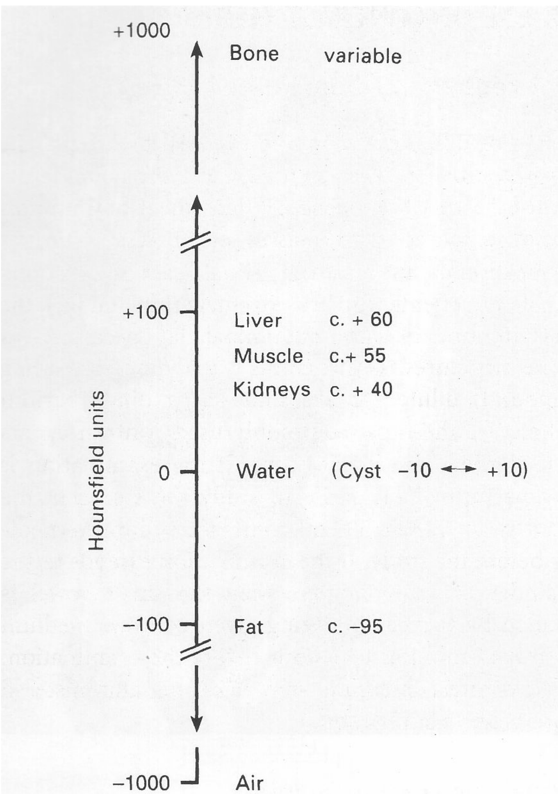
CBIR Applications for Anatomical Structures Retrieval

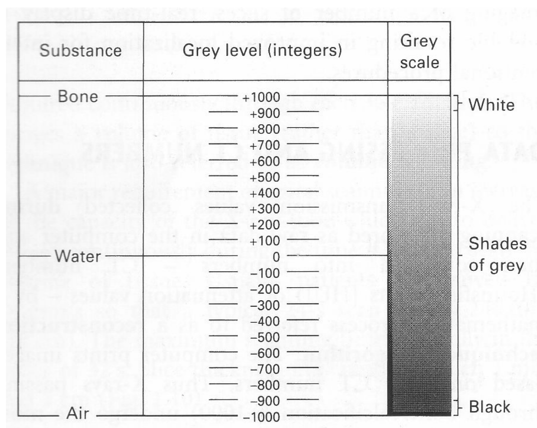
Evaluation of the CBIR systems:

- Retrieval performance:
  - precision & recall
- Similarity measures
  - chi-square, Euclidean distance, Minkowski distance, etc
- Type of features
  - texture features: statistical, structural, filter-based
- Type of retrieved objects
  - images/regions of interest/patches

Project 2: ***texture-based visualization of soft tissues***

Goal: Finding the relationships among the soft tissues with respect to texture information

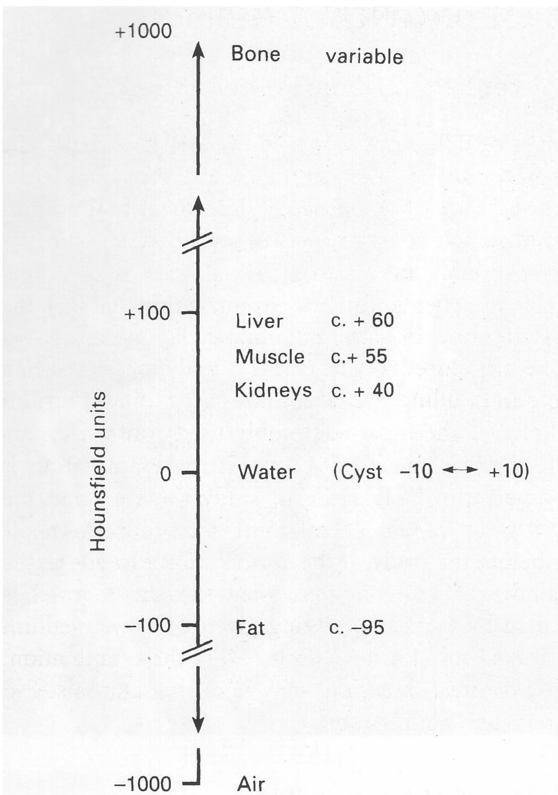


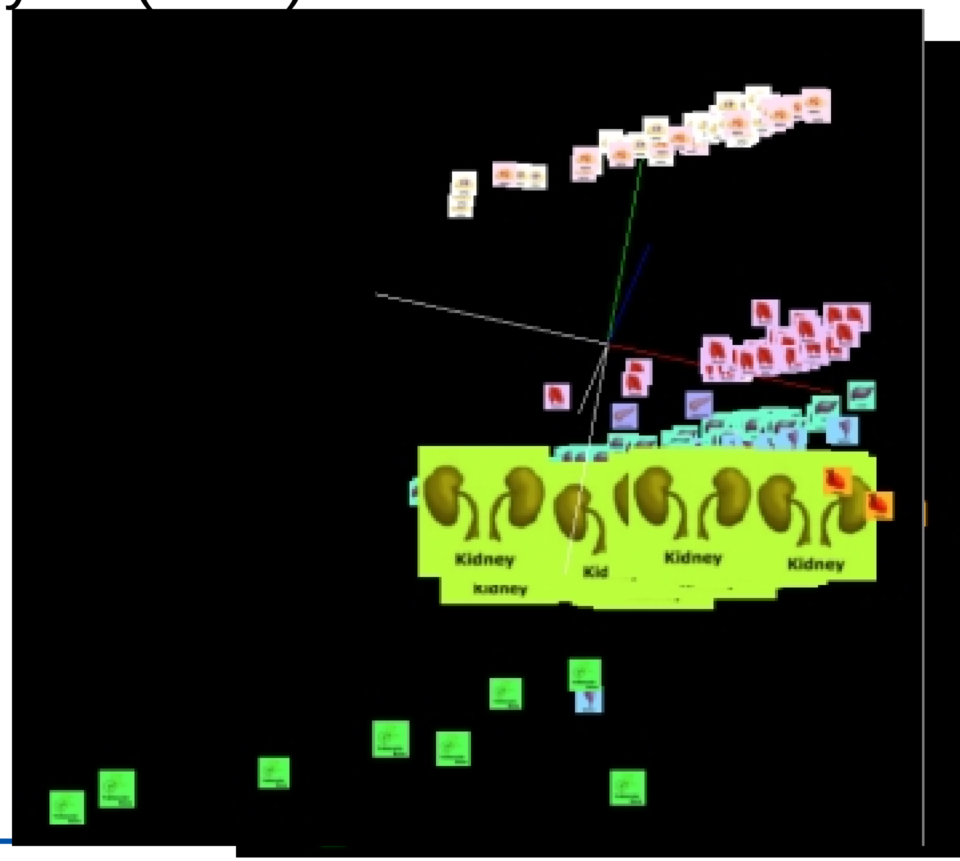


Substance	Texture descriptors	Texture Scale
Bone Water Air	?	

Project 2: texture-based visualization of soft tissues

Co-occurrence Texture Feature Space using Principal Components Analysis (PCA)





Project 2: texture-based visualization of soft tissues

Texture Representation:

- Co-occurrence texture spaces
- Markov Random Fields (MRF) spaces
- Gabor Filters spaces

Low - dimensional texture feature spaces:

Principal Component Analysis
Factor Analysis
Multidimensional Scaling

Ndaona Software:

http://people.cs.uchicago.edu/~dinoj/ndaona/

References

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[2] National Alliance for Medical Image Computing (NAMIC): http://na-mic.org (presentation by Ron Kikinis, M.D.)

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