DePaul CTI

Tutorial 2: Computer-Aided Diagnosis Systems

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Medical Informatics: Definitions

- **Medical Information Science** is the science of using system-analytic tools . . . to develop procedures (algorithms) for management, process control, decision making and scientific analysis of medical knowledge. (E.H. Shortliffe)

- **Medical Informatics** comprises the theoretical and practical aspects of information processing and communication, based on knowledge and experience derived from processes in medicine and health care. (J.H. van Bemmel)

- *Other names:* medical computer science, computer applications in medicine, health informatics

Processing and Analysis

- **Medical Image Processing** deals with the development of problem specific approaches to enhancement of raw medical data for the purposes of selective visualisation as well as further analysis.

- **Medical Image Analysis** concentrates on the development of techniques to supplement the mostly qualitative and frequently subjective assessment of medical images by human experts; it provides a variety of new information that is quantitative, objective and reproducible.

Computer Aided Diagnosis

- **Computed Aided Diagnosis (CAD)** is diagnosis made by a radiologist *when the output of computerized image analysis methods has been incorporated into his or her medical decision-making process*.

- CAD may be interpreted broadly to incorporate both
  - the detection of the abnormality task and
  - the classification task: likelihood that the abnormality represents a malignancy

Motivation for CAD systems

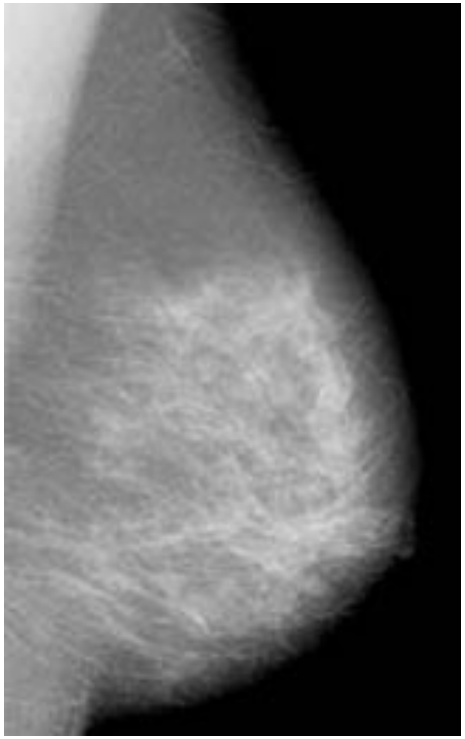
The amount of image data acquired during a CT scan is becoming overwhelming for human vision and the overload of image data for interpretation may result in oversight errors.

Computed Aided Diagnosis for:

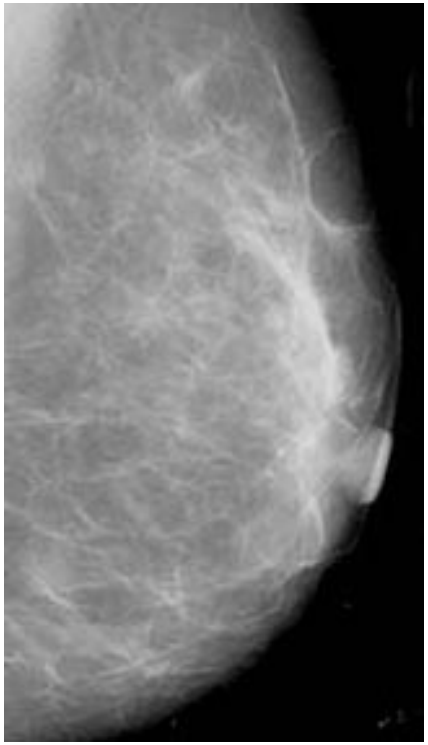
- **Breast Cancer**
- **Lung Cancer**
  - A thoracic CT scan generates about 240 section images for radiologists to interpret.
- **Colon Cancer**
  - CT colonography (virtual colonoscopy) is being examined as a potential screening device (400-700 images)

CAD for Breast Cancer

- A mammogram is an X-ray of breast tissue used as a screening tool searching for cancer when there are no symptoms of anything being wrong. A mammogram detects lumps, changes in breast tissue or calcifications when they're too small to be found in a physical exam.

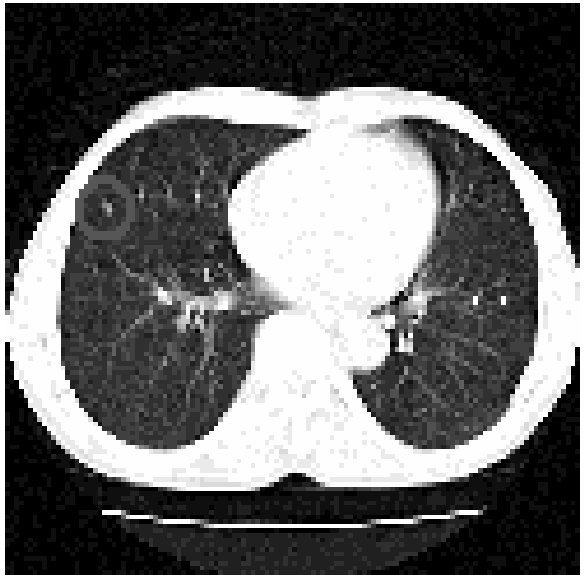


- Abnormal tissue shows up a dense white on mammograms.
- The left scan shows a normal breast while the right one shows malignant calcifications.



CAD for Lung Cancer

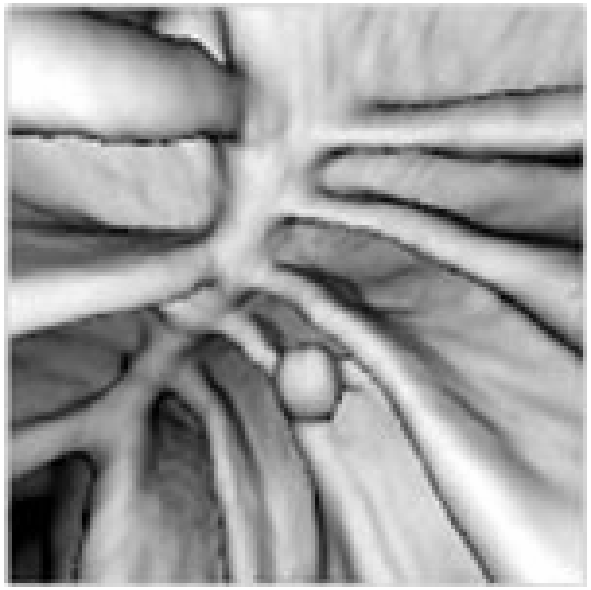
- Identification of lung nodules in thoracic CT scan; the identification is complicated by the blood vessels
- Once a nodule has been detected, it may be quantitatively analyzed as follows:

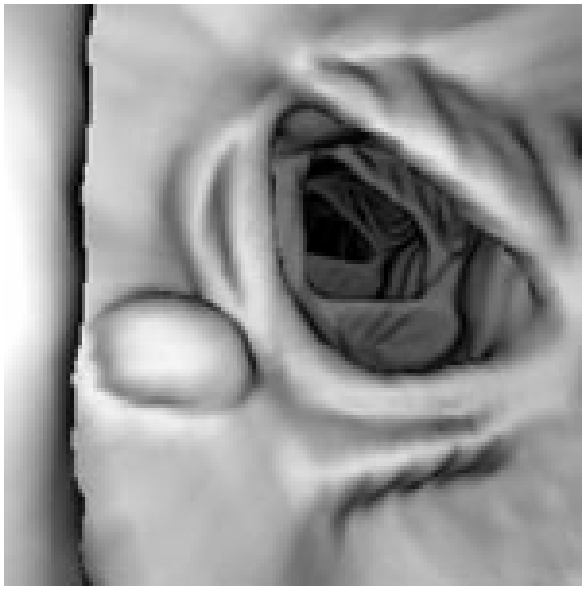


- The classification of the nodule as benign or malignant
- The evaluation of the temporal size in the nodule size.

CAD for Colon Cancer

- Virtual colonoscopy (CT colonography) is a minimally invasive imaging technique that combines volumetrically acquired helical CT data with advanced graphical software to create two and three-dimensional views of the colon.

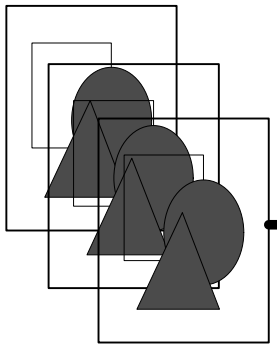




Three-dimensional endoluminal view of the colon showing the appearance of normal haustral folds and a small rounded polyp.

Role of Image Analysis & Pattern Recognition for CAD

- An overall scheme for computed aided diagnosis systems



- Breast Images
- Thoracic Images

Organ Segmentation

- Breast Boundary
- Lungs
- Colon

Lesion / Abnormality Segmentation

- Nodule
- Polyps

Feature Extraction

- Texture
- Shape
- Geometrical properties

Classification

- Malignant
- Benign

Evaluation & Interpretation

Image Segmentation

- Boundary extraction
- Region growing
- Gray-level histogram thresholding
- Deformable models
  - snakes (active contour mappings)
- Level Sets methods

Image Segmentation: Example 1

Gray-level histogram thresholding for lung segmentation

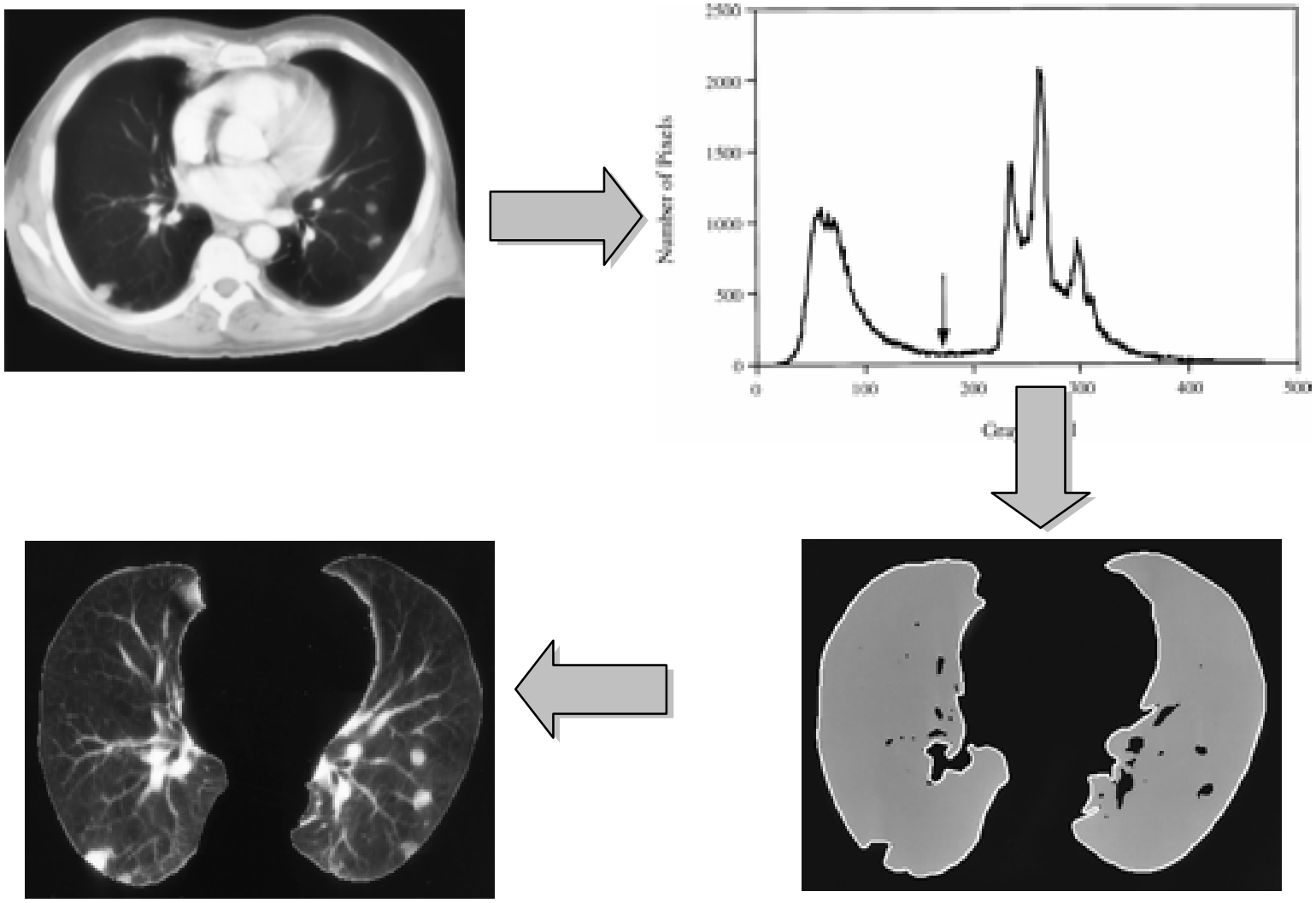
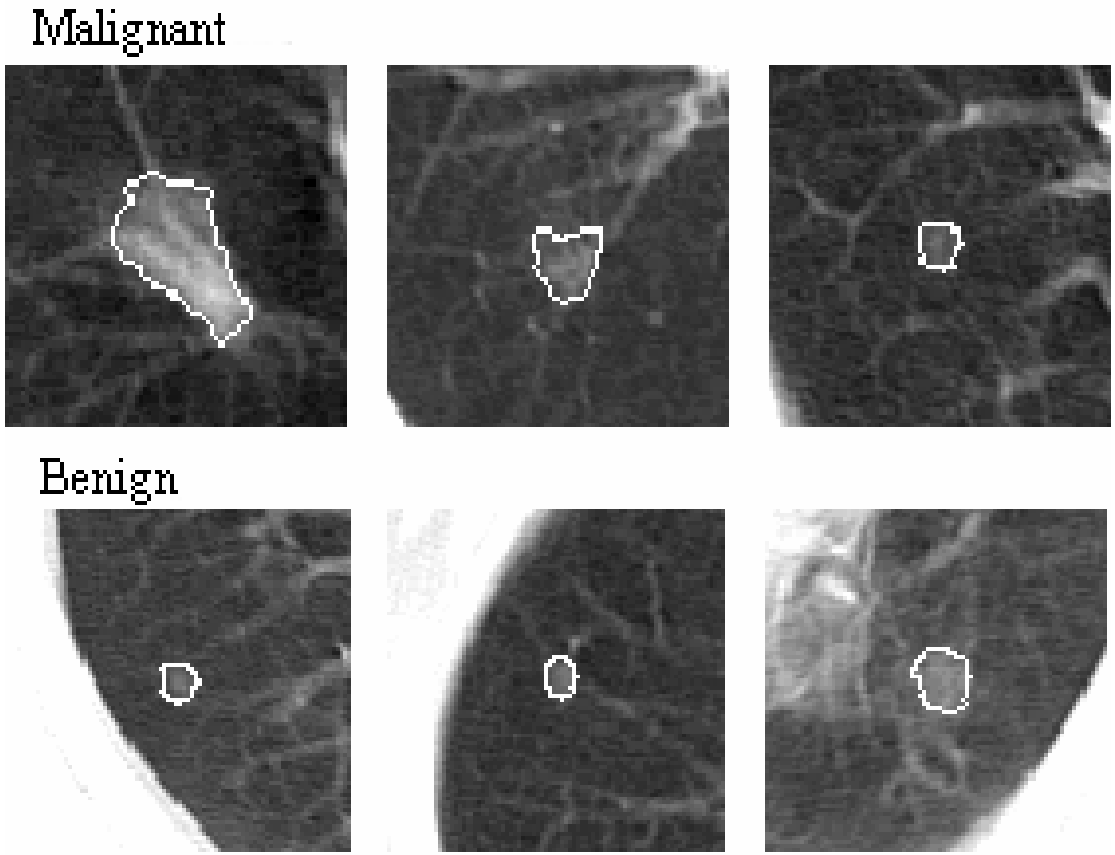


Image Segmentation: Example 1

Nodule segmentation



Extracted nodule regions by the automated nodule segmentation

Feature extraction

Automatic extraction of features (mathematical descriptors) from digital image that may or may not be otherwise perceived by human observer:

- Shape
- Texture
- Geometrical features

Such extraction may be performed at *pixel level or region level (*that region previously delimited as suspect in pre-processing stage) depending on the task to be performed.

Classification

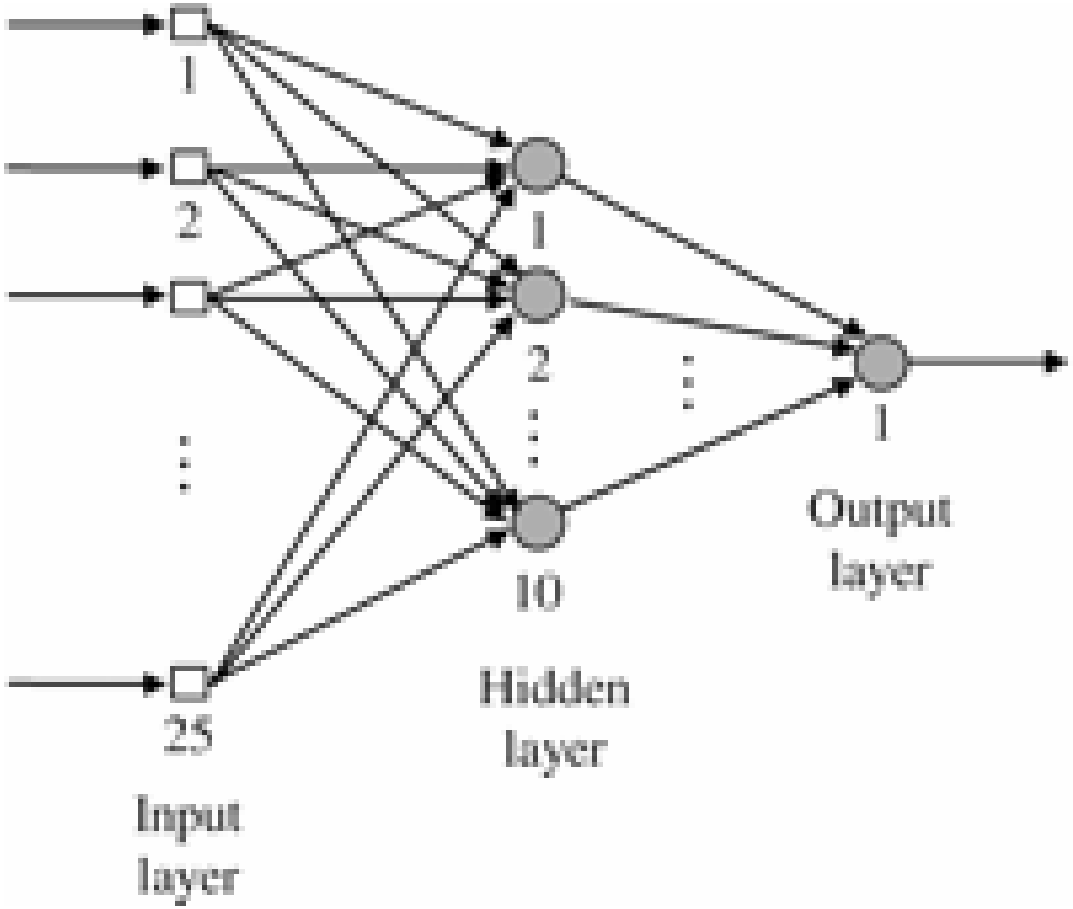
- Rule-based Methods
- Discriminant Analysis
- Bayesian Method
- Artificial Neural Networks
- Fuzzy Logic

Classification: Example

Artificial Neural Network

Feature vector:

F_1
F_2
F_3
.
.
.
F_{25}



input output

Abnormality type:

- Benign
- Malignant

Evaluation & Interpretation

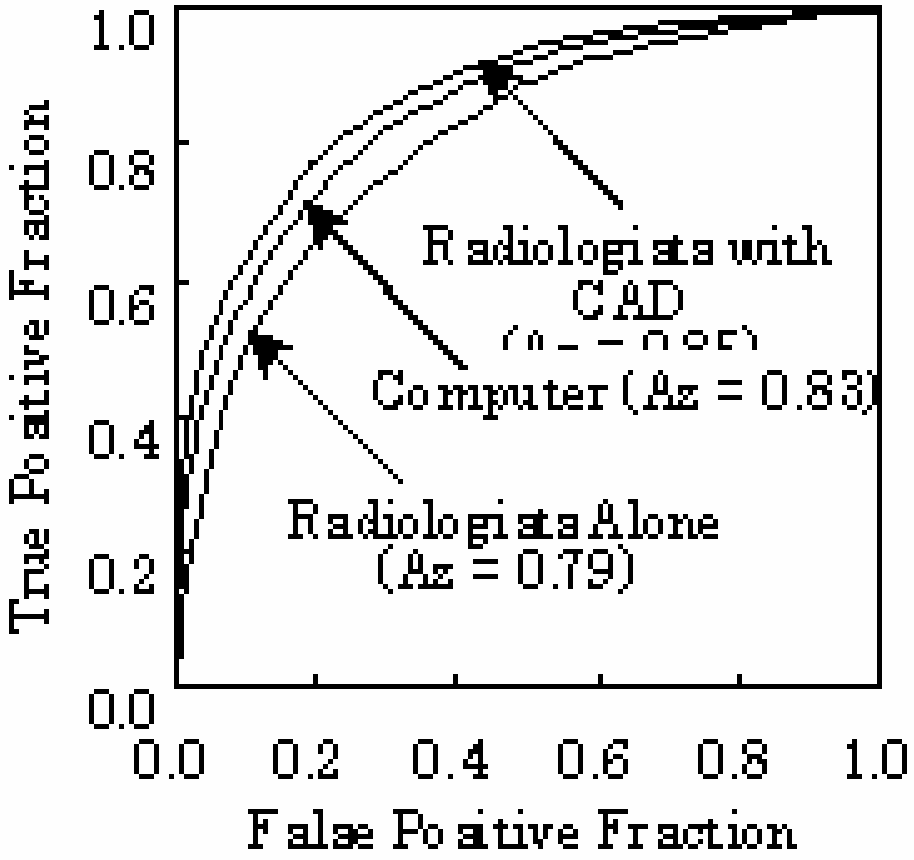
- *Sensitivity:* the ratio between true positives and total positives
- *Specificity:* the ratio between true negatives and total negatives
- Receiver Operator Characteristic (ROC)

A *true positive* is an abnormality classified as malignant when it is actually malignant.

A *true negative* is an abnormality classified as benign when it is actually benign.

Evaluation & Interpretation

- Receiver Operator Characteristic (ROC) curves for distinction between benign and malignant nodules on high-resolution CT.



Key Challenges in CAD

- Integration of the macro (organ) and the micro (molecular and cellular level) analysis
- Cooperation between image acquisition and image analysis and integration of different imaging modalities
- Development of appropriate validation and evaluation approaches
  - formation of common databases
  - need to aware of other related research communities of a variety of clinical disciplines

Ideal CAD Workstation?

It will have the human abilities

- to transfer acquired knowledge to new tasks,
- to adapt to the diagnostic problem,
- to choose image features that are relevant to the clinical task and to analyze the image
- to offer diagnostic suggestions, and, finally,
- to justify the suggestions on the basis of available reference data.

That CAD system will be a true partner to the diagnostic radiologist.

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