ADVANCED TOPICS IN BIOMEDICAL ENGINEERING

Topic 3: Computer Aided Detection and Diagnosis

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Computer Aided Diagnosis (CAD)

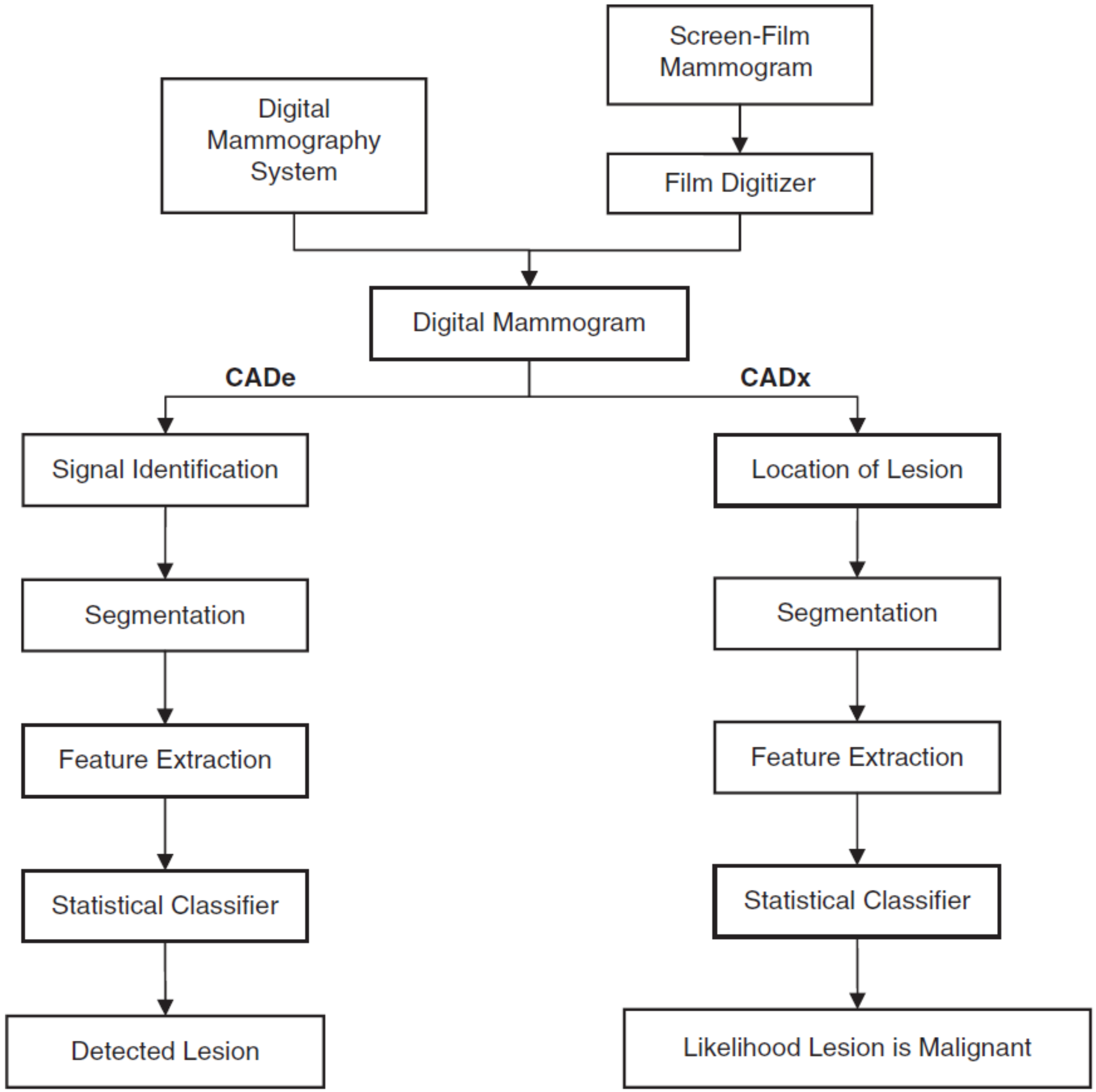
- Computer-aided diagnosis (CAD) is defined as a diagnosis made by a radiologist who uses the output of a computer analysis of the images when making his/her interpretation
- Computer-aided detection (CADe)
  - Identify and mark suspicious areas in an image
  - Goal of CADe is to help radiologists avoid missing a cancer
  - Used with “Screening Radiology”
- Computer-aided diagnosis (CADx)
  - CADx help radiologists decide if a woman should have a biopsy or not
  - Report the likelihood that a lesion is malignant
  - Used with “Clinical Radiology”

Goals of CAD

- Improving radiologists' performance
- Reduce intra- and inter-variability of radiologists
- It is also hoped that CAD can improve radiologists' productivity

- Estimating the risk of a woman to develop breast cancer (?)

Methodology



Example CADx User Interface

Clinical Studies for CADe

Study lead author	CADe stand-alone performance	Total no. of cases (no. of cancers)	Number of readers	Readers unaided	Readers aided	p-value
Chan et al. (1990)	87% sens., 3 false cluster/image	60 (30)	15	AUC = 0.94	AUC = 0.97	<0.001
Kegelmeyer et al. (1994)	100% sens. 0.28 false detections per image	85 (36)	4	Sens = 81% Spec = 96%	Sens. = 93% Spec = 97%	0.027 0.49
Taylor Study 1 (Taylor et al. 2005)	R2 ImageChecker version 2.2 (75% sens., 1.9 false detections per image)	180 (60)	50	Sens = 0.78; 95% CI: (0.76–0.80) Spec = 0.84 (0.81–0.86)	Sens = 0.78; 95% CI: (0.76–0.80) Spec = 0.84 (0.81–0.87)	Not statistically significant
Taylor Study 2 (Taylor et al. 2005)	Same as study 1 above	120 (44)	35	Sens = 0.77; 95% CI: (0.73–0.81) Spec = 0.85 (0.81–0.87)	Sens = 0.80; 95% CI: (0.76–0.84) Spec = 0.86 (0.84–0.88)	Not statistically significant
Gilbert et al. (2006)	R2 ImageChecker M1000 version 5.0	10,096 (315)	8	[a]Sens = 32.7% [a]RR = 6.5	Sens = 40.0% RR = 8.6	0.00 <0.001

[a]Double reading without CAD taken from original clinical readings

Clinical Studies for CADx

Study	Type of lesion	CADx stand-alone performance (AUC)	Number of cases (no. of cancers)	Number of readers	Readers' unaided AUC	Readers' aided AUC	*p*-value
Getty et al. (1988)	All	0.86	118 (58)	6	0.83	0.88	0.02
Jiang et al. (1999)	Calc	0.80	104 (46)	10	0.61	0.75	<0.0001
Chan et al. (1999a)	Mass	0.92	76 (39)	6	0.92	0.96	0.026
Leichter et al. (2000)	Mass	0.95	40 (18)	1	0.66	0.81	<0.001
Sklansky et al. (2000)	Calc	0.75	80 (23)	4	0.69	0.82	0.003
Huo et al. (2002b)	Mass	0.90	110 (50)	12	0.93	0.96	<0.001
Hadjiiski et al. (2004)	Mass	0.87	253 (138)	10	0.79	0.84	0.005
Hadjiiski et al. (2006b)	Mass	0.90	90 (47)	8	0.83	0.87	<0.05
Horsch et al. 2006	Mass	0.81, 0.93[a]	97	10	0.87	0.92	<0.001

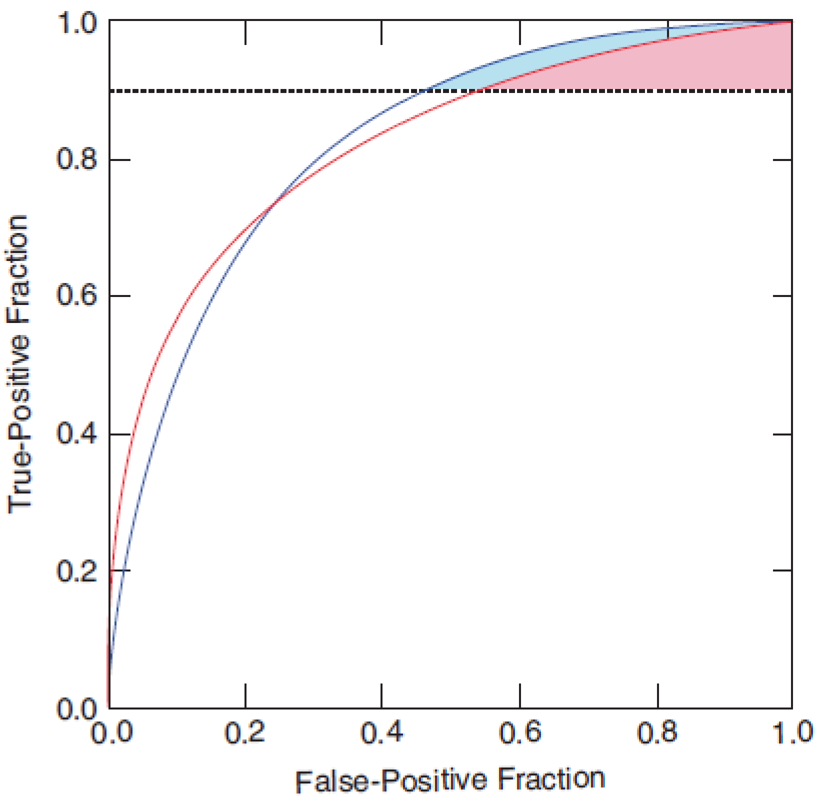
[a]CADx performance for mammograms, CADx performance for sonograms

Required Pixel Size

- Quality of digital image will affect the performance of CAD
- Two image sources for CAD
  - Digitized film mammograms
  - Full field digital mammograms (FFDM)
- Most important factor is the pixel size
  - Consistent with the pixel size in full digital mammograms, film mammograms are digitized for CAD with pixels ranging from 50-100 μm
  - It is generally believed that pixel size is only important for microcalcifications and not for masses

Evaluation of CAD Systems

- Graph shows two ROC curves with equal AUC, but the curves cross
  - One system is superior if high sensitivity is desirable, while the other system would be preferred for high specificity
  - "Partial area under ROC" (pAUC), where it is assumed that high sensitivity is desirable is shown in color for $_{0.9}$AUC



CADe as Pre-screen

- As the performance of CADe schemes has improved, the number of false detections has decreased while the sensitivity has improved or remained the same
- The performance of clinical CADe systems is now at the point where it may be possible to use CADe as a pre-screener of screening mammograms.
  - That is, before the cases are reviewed by a radiologist, a CADe scheme is run and cases without any detections are considered normal and not read by the radiologist
  - Goal here is to reduce the radiologists' workload
  - CADe scheme will pre-screen out "easy" cases
  - Problem: radiologists may become more exhausted, as every case will be "difficult"

Concurrent Reading with CADe

- Currently, CADe is used as a second reader, where the radiologist fi rst reads the images without CADe and then re-reads with the knowledge of the CADe findings
- An alternative paradigm is to have CADe as the first reader and have the radiologist verify (i.e., accept or reject) each CADe prompt
  - For this to be effective, the sensitivity of the CADe system must be very high
  - For mass detection, which is a very difficult task, sensitivity is not high enough
  - For clustered microcalcification detection, sensitivity is approximately 98%
- At this level of performance, it is conceivable that CADe could be the first reader, which is sometimes referred to as *concurrent reading*
  - CADe finds clustered microcalcifications at very high rate

Interactive CADe

- Instead of presenting all the CADe detections to the radiologist, the radiologist can mark suspicious area on a softcopy display and if the area was identified by the computer, the computer's likelihood that the area contains a cancer is given
- This information can be used by the radiologist in two ways. If the CADe scheme has a high negative predictive value, then if the area selected by the radiologist has a low likelihood of malignancy or if the computer did not select the region as suspicious, then the radiologist may have selected a region that does not contain an actual cancer.
- If the CADe scheme has high PPV and if the region selected by the radiologist has a high likelihood of malignancy, then there is a high probability that the selected region contains a cancer.
- Researchers achieved high PPV by operating the CADe scheme at a low false detection rate of 0.1 per image. They have shown previously that at this false detection rate, the performance of the CADe scheme was comparable with that of the radiologists, if the analysis was restricted to detections that were considered suspicious by the radiologists

CAD for Tomosynthesis and Breast CT

- Like other modalities, X-ray imaging of breast is becoming 3D
- Breast tomosynthesis and breast CT are emerging technologies that have a large potential to improve screening and diagnosis
- One of the potential drawbacks of these technologies is that a large volume of images is produced per breast
  - Screening mammogram produces two images of each breast, while a tomosynthesis exam could produce more than 100 images of each breast with large amount of data that the radiologist needs to review
  - CAD may play an important role in assisting radiologists, so that they do not overlook a cancer.

Assignments

- Read Chapter 6 entitled "Computer-aided Detection and Diagnosis" by Robert M. Nishikawa
- Read the following paper and think about how to implement the first- and second-order grey level parameters using built-in Matlab/Octave functions and also the kNN classifier:

  Yasser M. Kadah *et al.*, "Classification algorithms for quantitative tissue characterization of diffuse liver disease from ultrasound images," *IEEE Trans. Medical Imaging*, vol. 15, no. 4, pp. 466-478, August 1996.