New Image Processing Resources:

What is Brewing?

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Disclosure

Commercial relationships

1. **VisionGate, Inc**.: Dr. Reeves is a paid consultant and holds stock in the company. VisionGate is developing optical imaging technology for the analysis of individual cells.
2. **General Electric**: Dr. Reeves is a co-inventor on a patent and other pending patents owned by Cornell Research Foundation (CRF) which are non-exclusively licensed and related to technology involving computer-aided diagnostic methods, including measurement of nodules

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New Image Processing Resources:

What is Brewing? Wikipedia Brewing (Tea)

- A **tea party** is a formal, ritualized gathering for afternoon tea

- **1903 Tea bag**
- Tea bags were invented by Thomas Sullivan around 1903. The first tea bags were made from silk.
- **Brewing** is the production of beer through steeping a starch source in water and then fermenting with yeast.

http://www.jitterbuzz.com/coftrip.html

Outline

1. Review of state-of-the art
   1. Detection,
   2. Characterization,
   3. Change measurement
2. New directions for computer methods
   1. Make computer algorithms aware of human anatomy
   2. Review other conditions in addition to lung cancer
   3. Data mining of large datasets

Computer Aided Diagnosis (CAD)

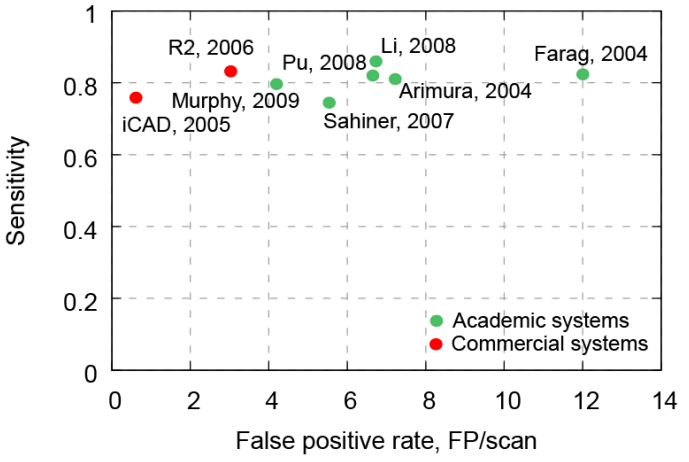
- Recent CAD systems understand some basic geometry and little density

Geometry	Representation
Blob	Nodule
Cylinder	Vessel
Planar Surface	Pleural Surface

Lung Cancer CT image Analysis tasks

Status	Undiagnosed	Diagnosed
Indication	LC symptoms Other symptoms Screening	Lung Cancer
Task	Diagnosis	Therapy
Nodules	Small (< 15 mm)	Large (> 15 mm) Small (mets)
Primary Task	1. Detection 2. Diagnosis (Growth Rate)	Change +/-

Reported detection performances*



* Studies with at least 50 cases or 100 nodules

1. Pulmonary nodule detection

Summary

- Most recent studies on low-dose ~ 1 mm slice

Feature	Range	[outlier]
Minimum Nodule Size	1 – 4 mm	
Sensitivity%	70 - 90	
False Positives/ scan	3 – 12	[0.55]
Number of cases	20 – 450	[813]
Number of cases	122 – 470	[3981]

1. Pulmonary nodule detection

Discussion

•Sensitivity of 80 – 90% is an asset to radiologists in clinical practice.

•With current algorithm strategies sensitivity may improve to 95%

•Major barrier to improved performance: data set size Many (infrequent) nodule geometries are underrepresented

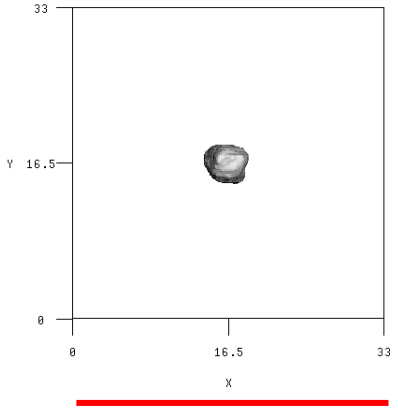
•Public available databases today:

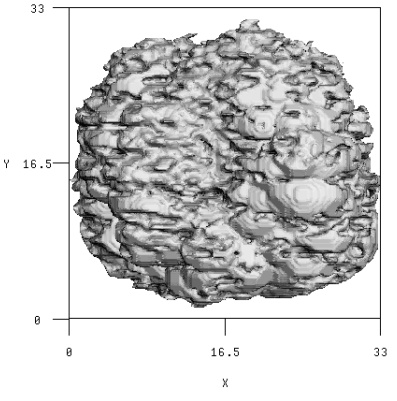
- LIDC 400 cases
- VIA/ELCAP 50 cases

•Number of cases needed for algorithm development > 10,000

Problem

- Malignancy status from a single CT scan:

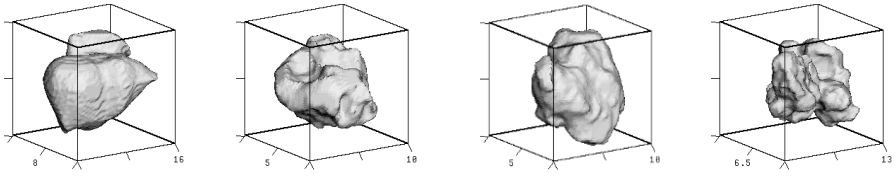




33 mm

Problem

- Malignancy status from a single CT scan:



Malignant **Benign**

2. Pulmonary nodule Diagnosis

- Recent work: Features of a single scan

Study	Year	# nodules	# benign	#malignant	AUC
Kawata	2001	128	95	33	0.87
Aoyama	2003	489	413	76	0.85
Shah	2005	81	33	48	0.92
Suzuki	2005	489	413	76	0.88
Way	2006	96	52	44	0.83
Jirapatnakul	2007	259	92	167	0.69

2. Pulmonary nodule Diagnosis

Summary

•Number of malignant nodules for training: 33 – 167

•Area under the curve is biased by data set distribution: a realistic AUC for just 10 mm nodules is likely < 0.7

Discussion

•The current performance is not good enough for clinical use

•Major barrier to improved performance: data set size

•Public available databases today: none

•Number of cases needed for algorithm development > 10,000

Pulmonary Nodule Change Measurement

Diagnosis

- Main target: small nodule size < 15 mm
- Very highly effective when done correctly
  - Interscan interval can be adjusted to ensure reliable diagnosis
- AUC in found to be 0.98 in recent study

Therapy

- Ongoing efforts to validate measurement methods
  - Need to know shortest scan interval to indicate +/- change
- Main target: large nodule size > 15 mm (except for mets)
- Scans for therapy are typically thick slice

Nodule Change Measurement

- Multiple scan growth measurement (Stable cases)

Author	Year	# nodules	Size Range	Software	Variation
Kostis	2004	94	2 – 10	Research	-29.8%, 33.4%
Reeves	2006	50	2 – 12	Research	18.3%, 18.3%
Marchiano	2009	233	2.1 – 11.8	Siemens	-27%,27%

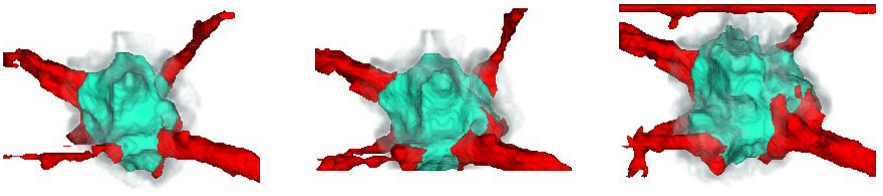
- Zero-change and actual change data sets

Author	Year	# nodules	Size Range	Software	Variation
Wormanns	2004	151	2.2 – 20.5	Siemens	-20.4%,21.9%
Goodman	2006	43	4.0 – 19	GE	-25.6%,25.6%
Gietema	2007	218	3.2 – 9.7	Siemens	-21.2%,23.8%
Zhao	2009	32	11 – 93	Research	-12.1%,13.4%
Rampinelli	2009	83	5.0 – 10.0	GE	-38%,60%
VOLCANO	2009	49	4.0 – 24		
Biochange	2010	96	4.0 – 99.5		

Nodule Change Measurement: Diagnosis

Summary

- Research problem solved (requires a detailed protocol)
- Translational research study required for clinical practice



Sagittal-Coronal Views

Nodule Change Measurement: Therapy

Summary

- Current studies indicate that for small (> 2 mm, < 20 mm) nodules Limits of agreement in the order or 20+% for change measurement may be achieved.
- Less error for larger nodules when measured ***carefully.***

Discussion

- Technical details are important for good quantitative measurements
- Controlled thin-slice CT scanner protocols are a priority:
  - Ongoing work by DICOM and QIBA
- Calibration phantoms for better machine characterization
- Studies required to validate ***Change*** measurement accuracy for both small and large nodules in the therapy context.
  - Ongoing work by QIBA, Biochange, and Volcano

Nodule Change Measurement: Therapy

Discussion

- Available Zero-Change nodule pair Public Databases
  - Prevent Cancer Public Database: 27 cases
  - RIDER: 32 cases
- Other Public data bases
  - Prevent Cancer Database has numerous example documented cases (many thick slice)
  - RIDER has many undocumented cases (almost all thick slice)
- Needed: quality scan pairs of large nodules with thin slices
- Needed: A small number of benchmark scans with extensive documentation (VOCLANO)

VOLCANO Program

Goal: Provide standardized benchmarks results for pulmonary nodule change analysis

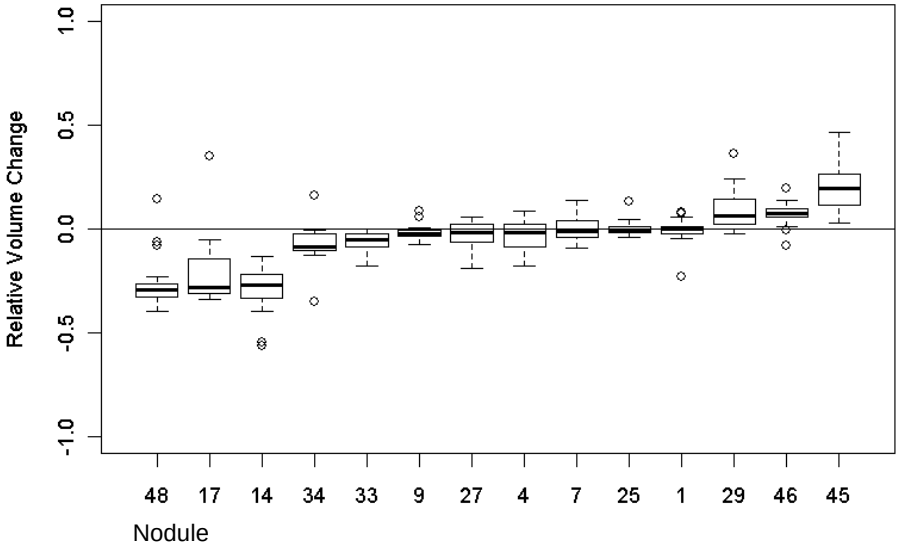
1. Establish a set of benchmark image pair cases
2. Conduct studies to document cases
3. Public database of cases and study results
4. Refine benchmarks with updates

VOLCANO Activities

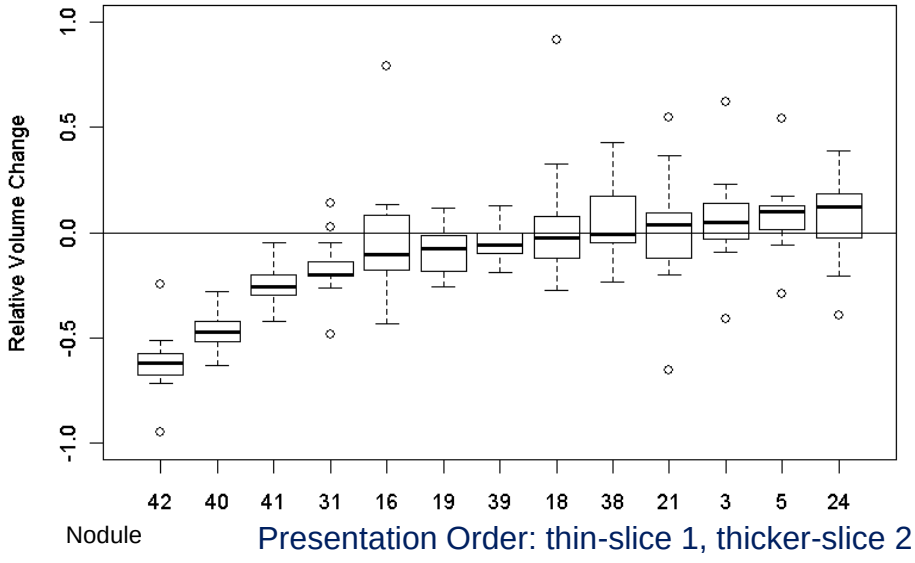
- VOLCANO ‘09
  - Results with 15 different automated methods
  - Zero-change, actual change, phantom
- VOLCAMAN ‘10
  - Manual marking over a web-based marking tool
  - Ongoing
  - Results to be compared to VOLCANO ‘09
- VOLCANO Benchmark Data
  - Data set with published results from all studies

- Second International workshop on pulmonary Image Analysis held in conjunction with MICCAI 2009
- An open challenge to all developers and users of ALL volumetric measuring tools
  - 49 CT scan pairs of lesions, all good quality, most1.25mm
  - Submit fractional change in size of lesions
  - Agreement between submissions will be analyzed
- Results
  - 13 groups and 17 computer methods participated in the challenge
  - Good agreement to other studies

Results: Group A zero-change, same slice thickness



Results: Group B
(zero-change, different slice thickness)



New Directions for CAD

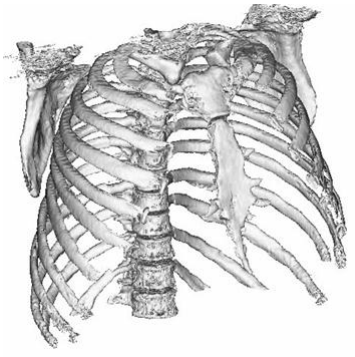
1. Make CAD systems aware of human anatomy
2. Review other conditions in addition to lung cancer
    1. Emphysema
    2. Airway measurements
    3. Coronary Calcium
3. Data mining of large datasets

New Directions

- Chest Frame of Reference
  - Map Chest CT to standard reference frame
  - A. Compare longitudinal patient scans
  - B. Compare Chest anatomy across a population
- Automated Chest Atlas
  - Totally automatic on low-dose CT thoracic images
  - Review and compare all chest organs to norms

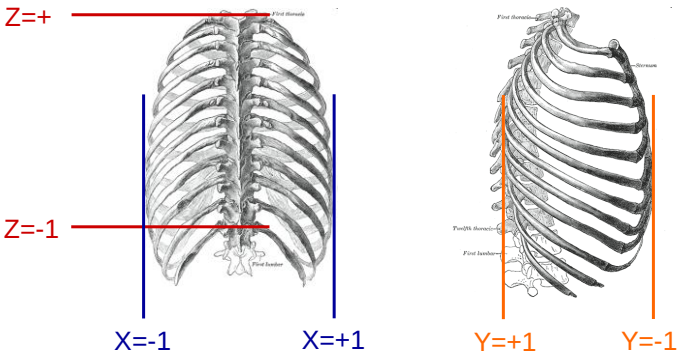
Chest Frame of Reference (CFOR)

- Identify a mapping between different chest images by using the bone structure as a reference
- Automatic bone segmentation is simple and robust



Chest Frame of Reference (CFOR)

- CFOR is built based on the rib cage of a given scan
- Defined with the reference points at -1.0 and +1.0 in the standardized coordinate system



Coordinate Mapping (CFOR)

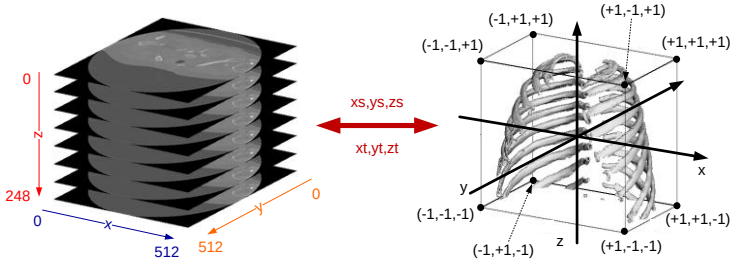
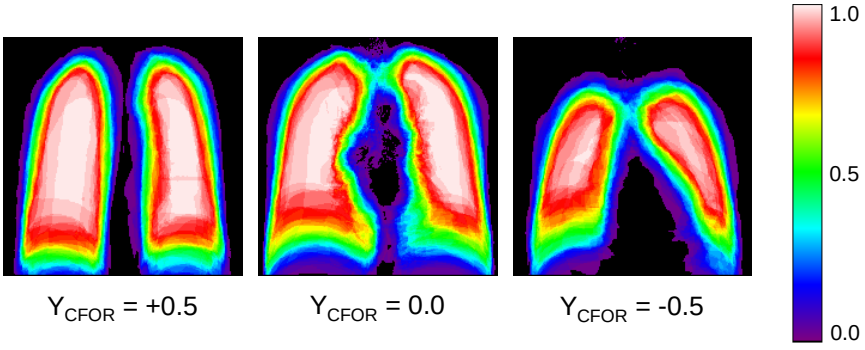


Image space **CFOR space**

- An image coordinate may be mapped to a CFOR coordinate and vice versa using an scale/translation vector
- Scale/translation vector (STV) is defined as:
  - **STV** = *<xs, ys, zs, xt, yt, zt>*

Lung Prior (Coronal Views)

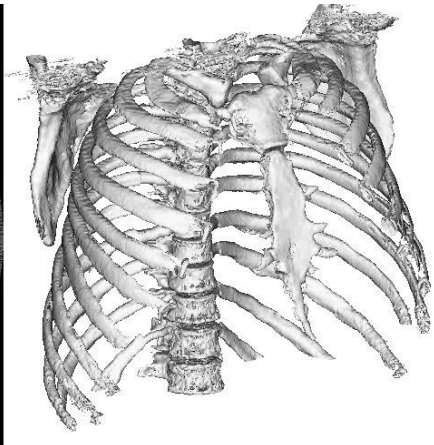
- Established using 50 cases



Y_{CFOR} = +0.5 Y_{CFOR} = 0.0 Y_{CFOR} = -0.5

- Facilities automatic comparison between cases and the detection of abnormalities

Chest Atlas Visualization 36



Summary

New directions for computer methods

1. Make computer algorithms aware of human anatomy
2. Make available a sufficient number of images for algorithm development
3. Review other conditions in addition to lung cancer
4. Data mining of large datasets