Computer-aided detection in DBT (digital breast tomosynthesis)

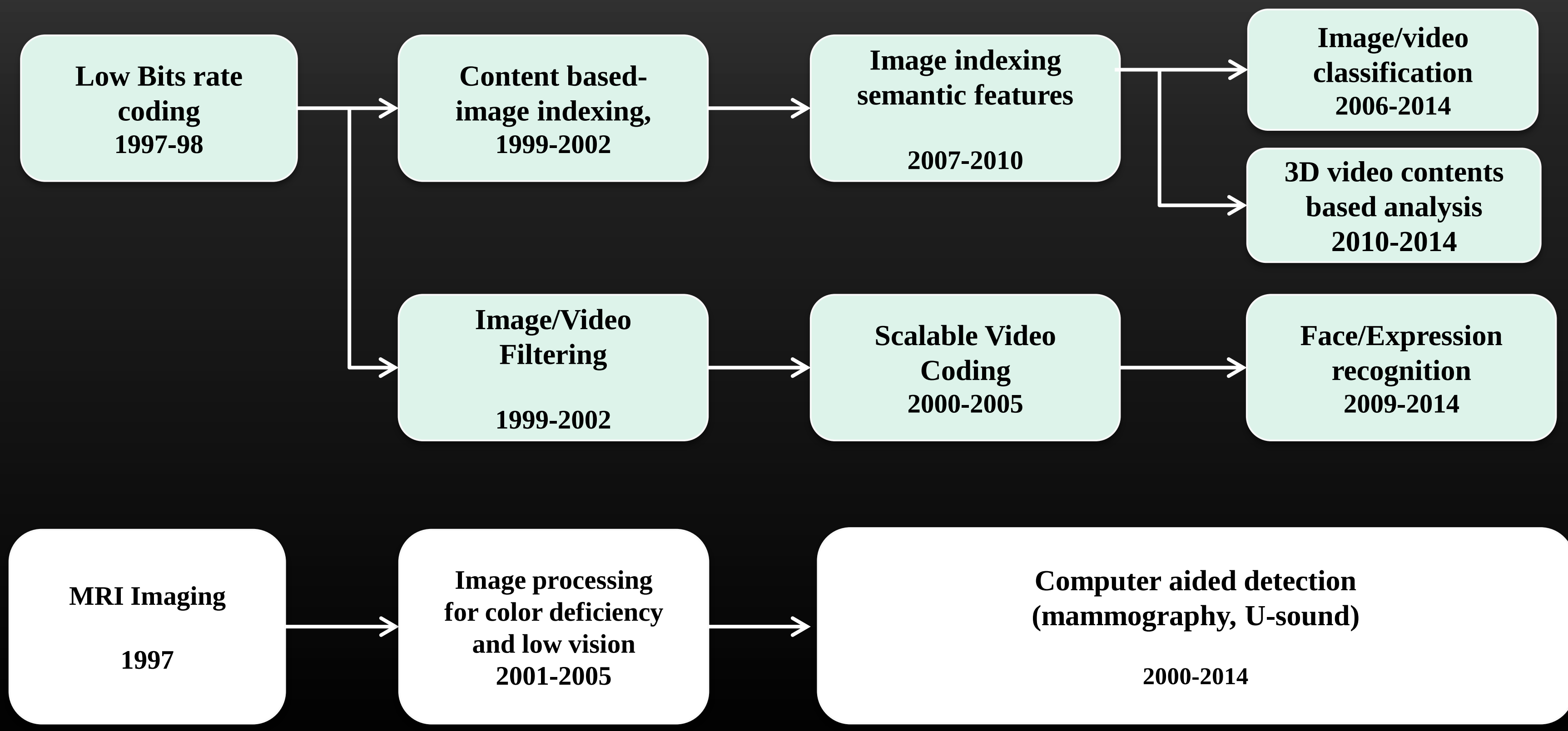
2015 Summer

Prof. Yong Man Ro
Image and Video Systems (IVY) Lab.,
Department of Electrical Engineering, KAIST
ymro@kaist.ac.kr

IVY Lab (Image Video System. YM Ro Lab)

❖ Research history

Image Processing and Recognition



ivylab.kaist.ac.kr

- 104 SCI indexed papers, 242 International conference papers
- 11 MPEG standard technologies
- Spin off: Image filtering system, Color adaptation

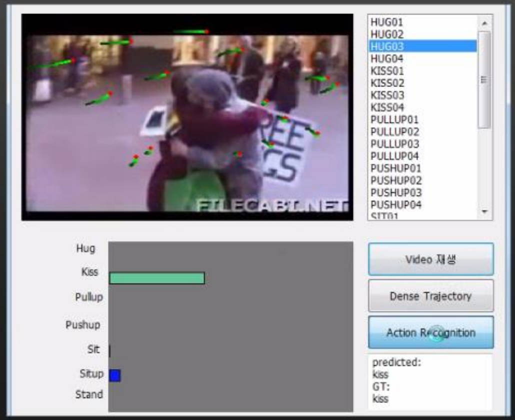
KAIST

IMAGE & VIDEO SYSTEMS Lab. since 1998

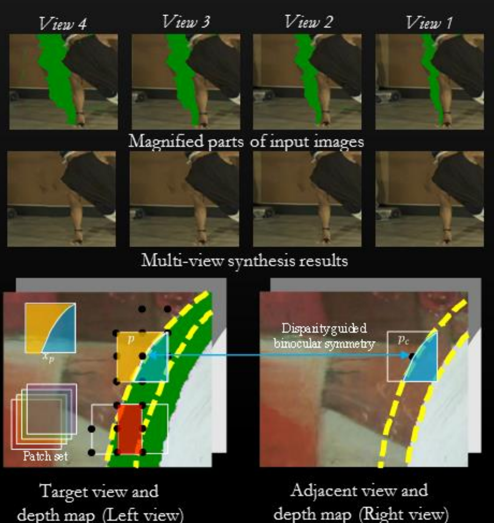
Current Research activities

Face recognition: Based on face quality assessment

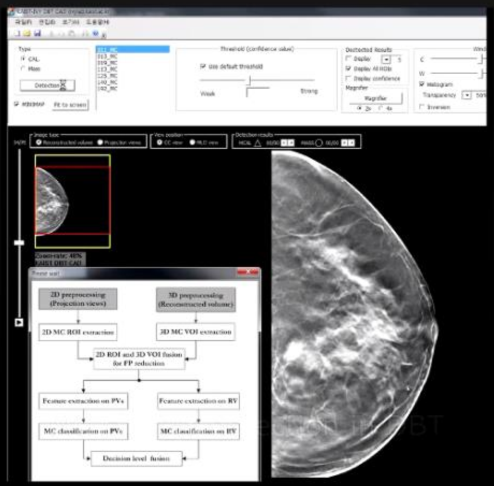
Facial expression recognition: Using color texture sparsity



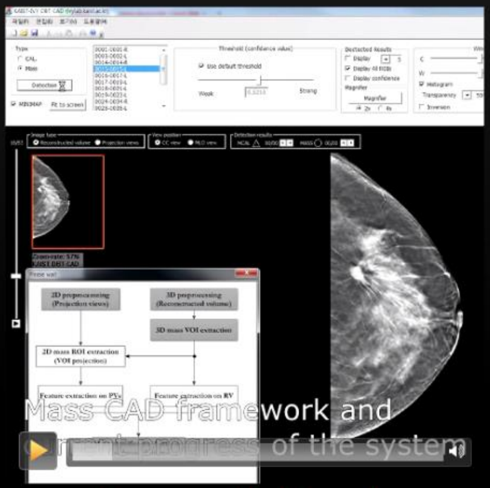
Video classification: Human action recognition using dense trajectory



3D processing: Binocular symmetric hole filling with global optimization



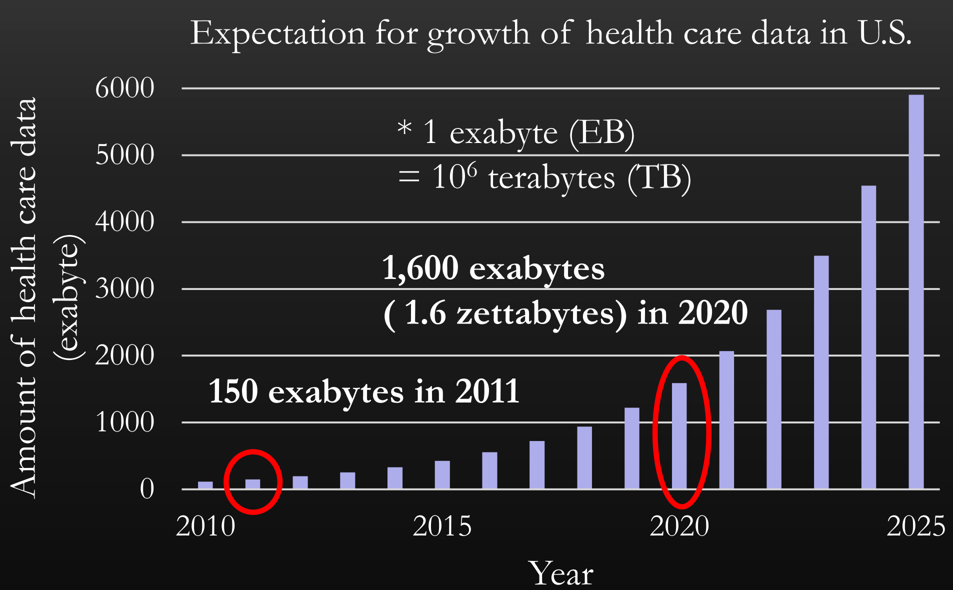
Computer aided detection: Microcalcification cluster detection in DBT



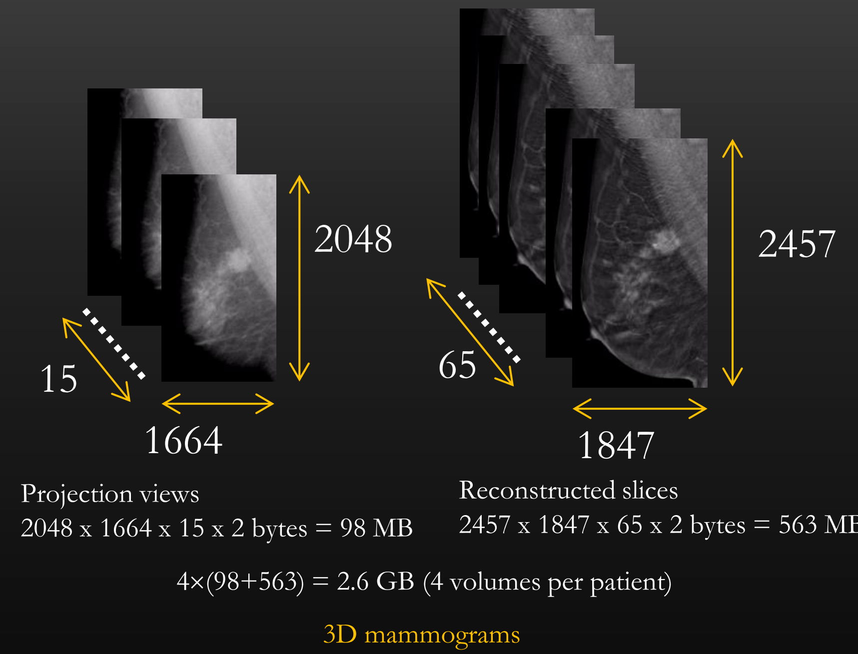
Computer aided detection: Mass detection in DBT

Medical images and size…

❖ **Explosion of medical data**



*** Portion of medical image: about 80%**



120MB - Mammograms

2.6GB - 3D mammograms (tomosynthesis)

20%-40%

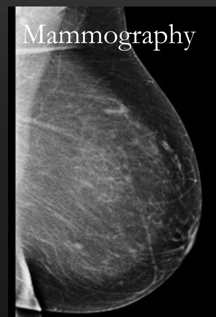
How can handle the big data?

W. Raghupathi and V. Raghupathi, "Big data analyrics in healthcare: promise and potential", Health Information Science and System, 2014.
SAP's Amit Sinha, "Big data's challenges and solutions towards producing real-time personalized medicine", Strata Rx 2013 conference

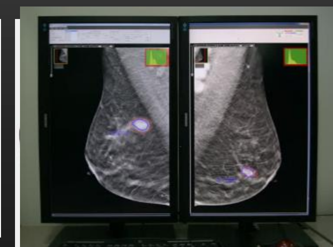
Cancer diagnosis with medical images

❖ General procedure for breast cancer screening

Mammography



First reading



Second reading

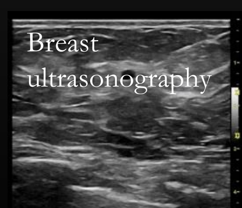
* Double reading, which is standard practice in the UK, significantly improves the sensitivity and specificity

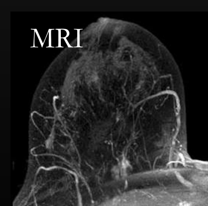
Computer aided detection (CAD) can replace the second reader

Increasing throughput and effectiveness of the screening

Uncertain case

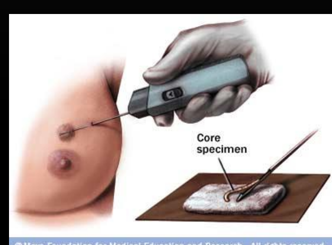
Additional imaging: breast ultrasonography or MRI, etc.



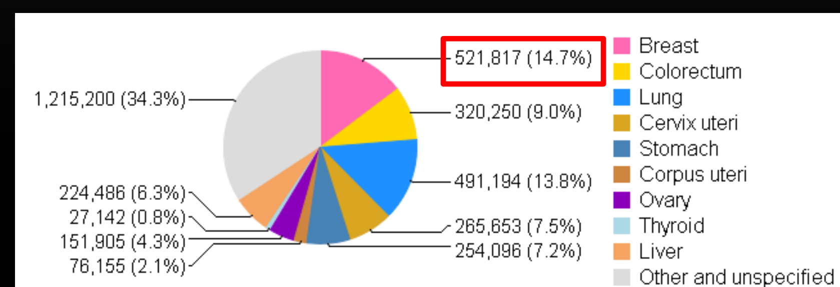


Highly suspicious case

Biopsy or follow up study

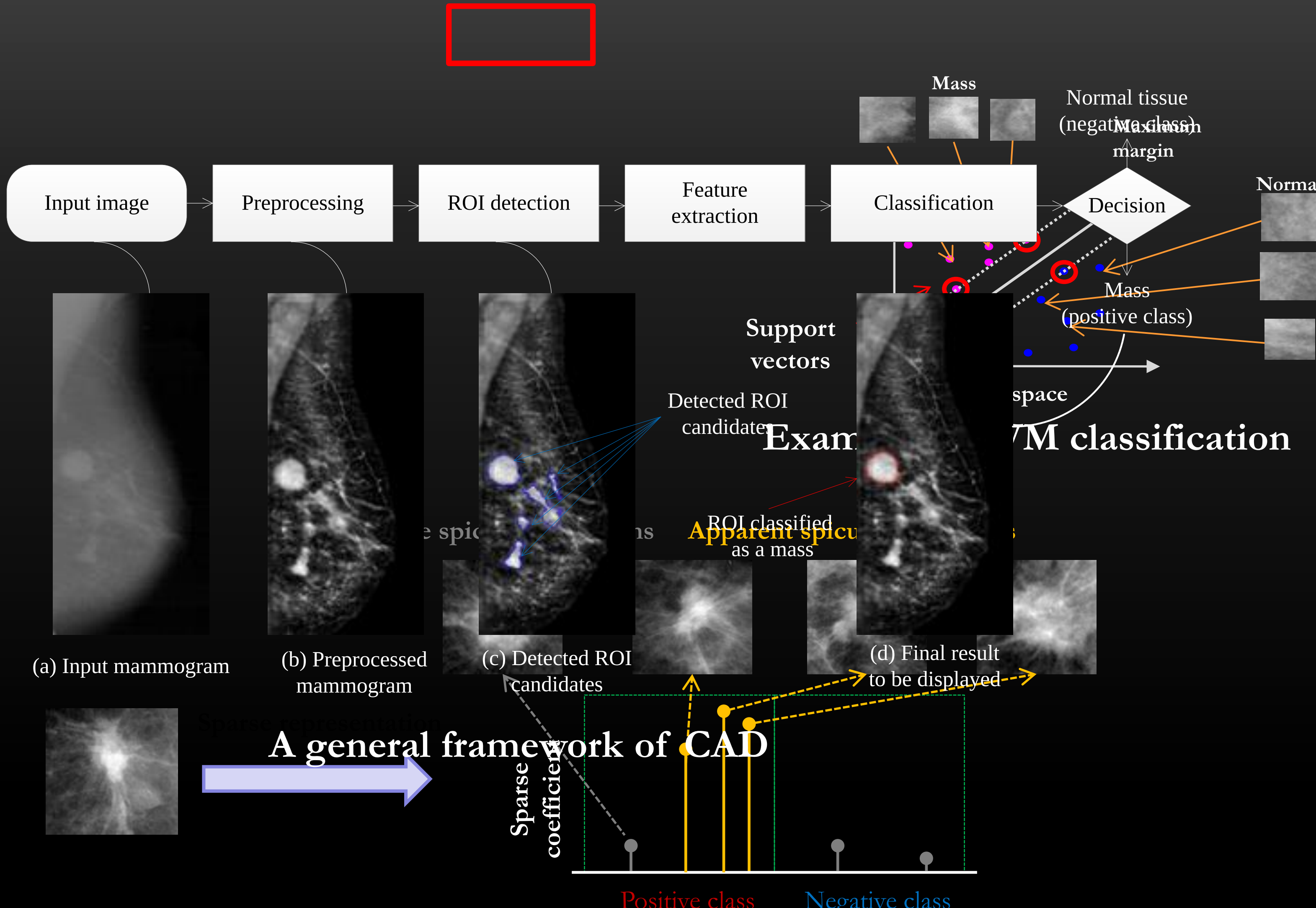


Breast cancer is the most cause of cancer related death on woman [1]



E. Warner "Breast cancer screening," The New England Journal of Medicine, 2011
"Breast Cancer Screening - Thermography is Not an Alternative to Mammography: FDA Safety Communication", U.S. Food and Drug Administration, 2011
[1] "GLOBOCAN 2012: Estimated cancer incidence, mortality and prevalence worldwide in 2012," *WHO (world health organization)*, 2012

Computer-aided detection via visual recognition



Example of sparse representation based classification

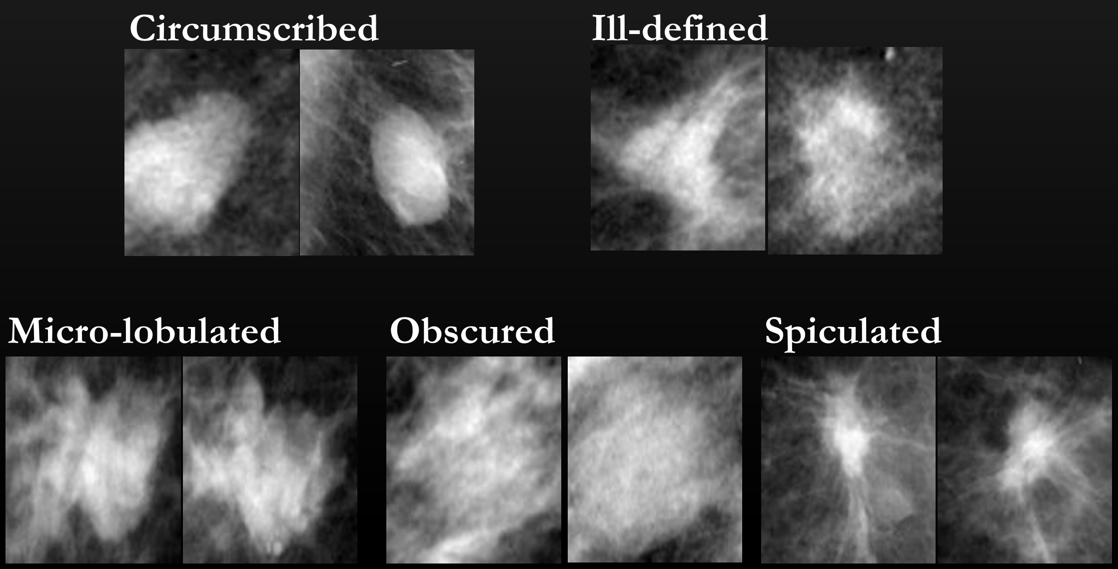
Image pattern of breast cancer in mammogram

❖ Mass

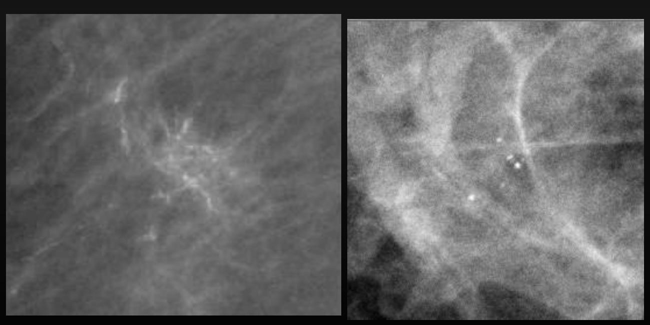
- Appeared more densely (brighter) than the surrounding tissues
- Breast masses present various margin types [1]

❖ Microcalcification

- Cluster of bright and small points
- 100 μm – 1mm size (1.5 – 15 pixels in 70 μm mammogram image)



Examples of various margins of breast mass



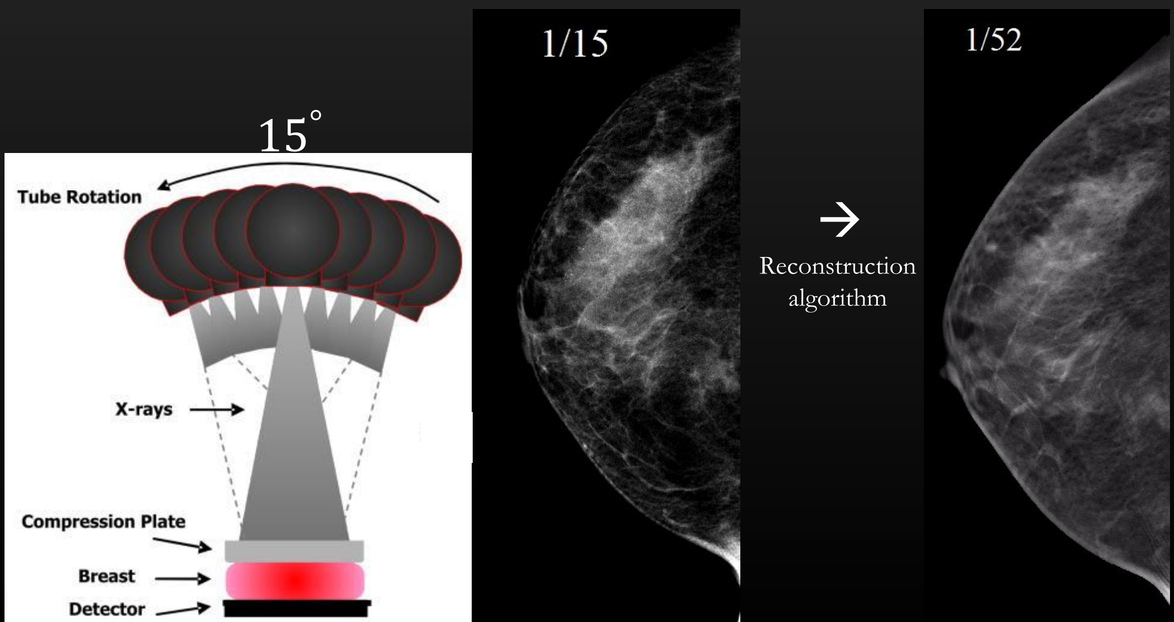
Examples of microcalcification

[1] Sylvia Heywang-Koebrunner, Ingrid Schreer, "Diagnostic breast imaging, second edition," in *Thieme*, 2001.

Modality for breast cancer screening

❖ History

Film mammography (1967) → Digital mammography (early 1990s-current) →3D digital breast tomosynthesis (DBT) (2011-developing)



(a) (b) (c)

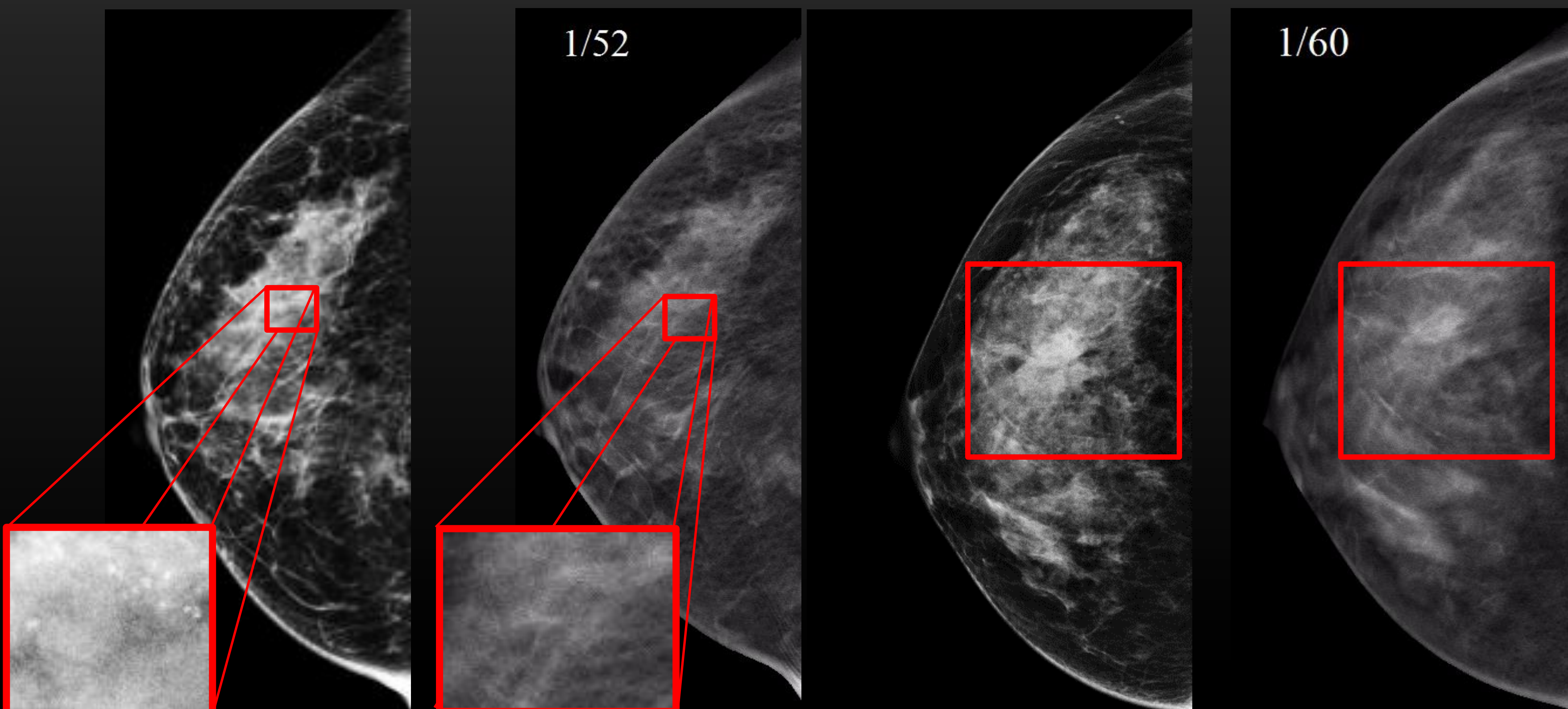
An illustrative example of (a) DBT acquisition geometry with (b) the projection views (**15 images**) acquired by the DBT (c) the reconstructed slices (**50~80 images**)

Examples of DBT data acquisition and breast cancer screening using DBT

Kontos, D. et al (2009): "Parenchymal Texture Analysis in Digital Breast Tomosynthesis for Breast Cancer Risk Estimation: A Preliminary Study"; Acad Radiol; v.16:283:298.
Video clips from University Hospitals (http://www.youtube.com/watch?v=InD5qpxTJgA)

2D DM vs. 3D DBT

- DBT could reduce tissue overlap in Digital Mammography (DM)
- DBT clearly shows breast cancers

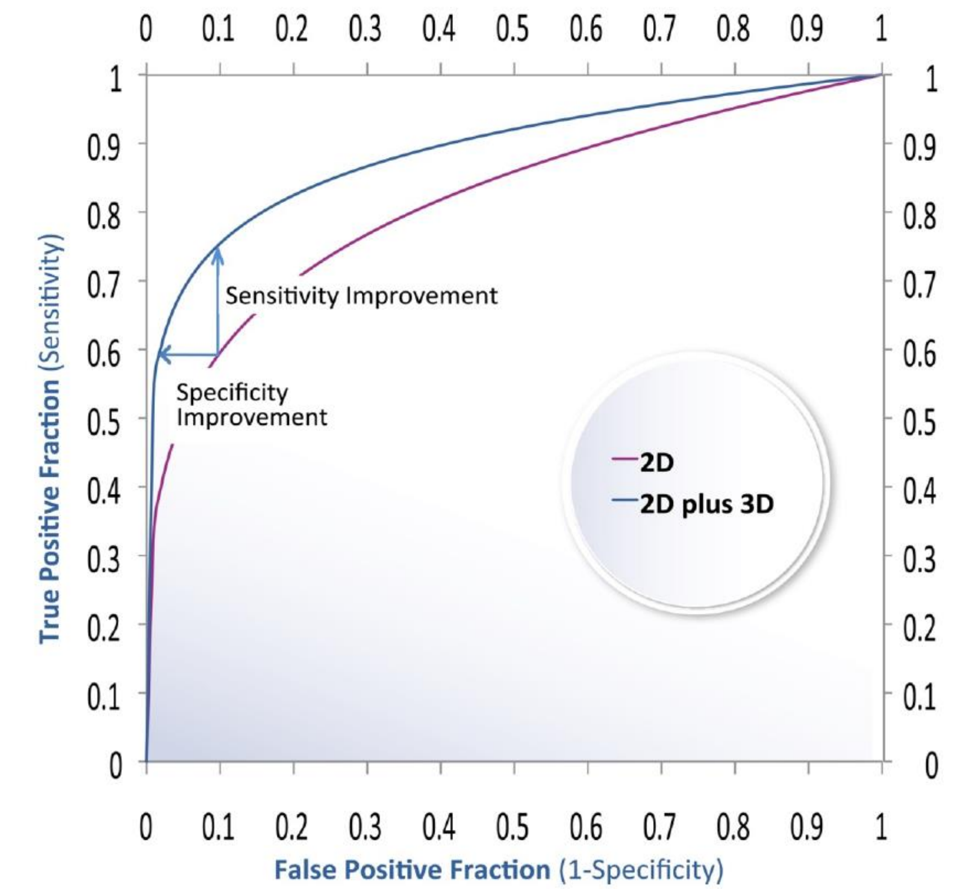


2D DM　　3D DBT　　2D DM　　3D DBT

Microcalcification　　Mass

Clinical reports: 2D vs. 2D+3D

❖ Advantages on screening using 2D DM + 3D DBT



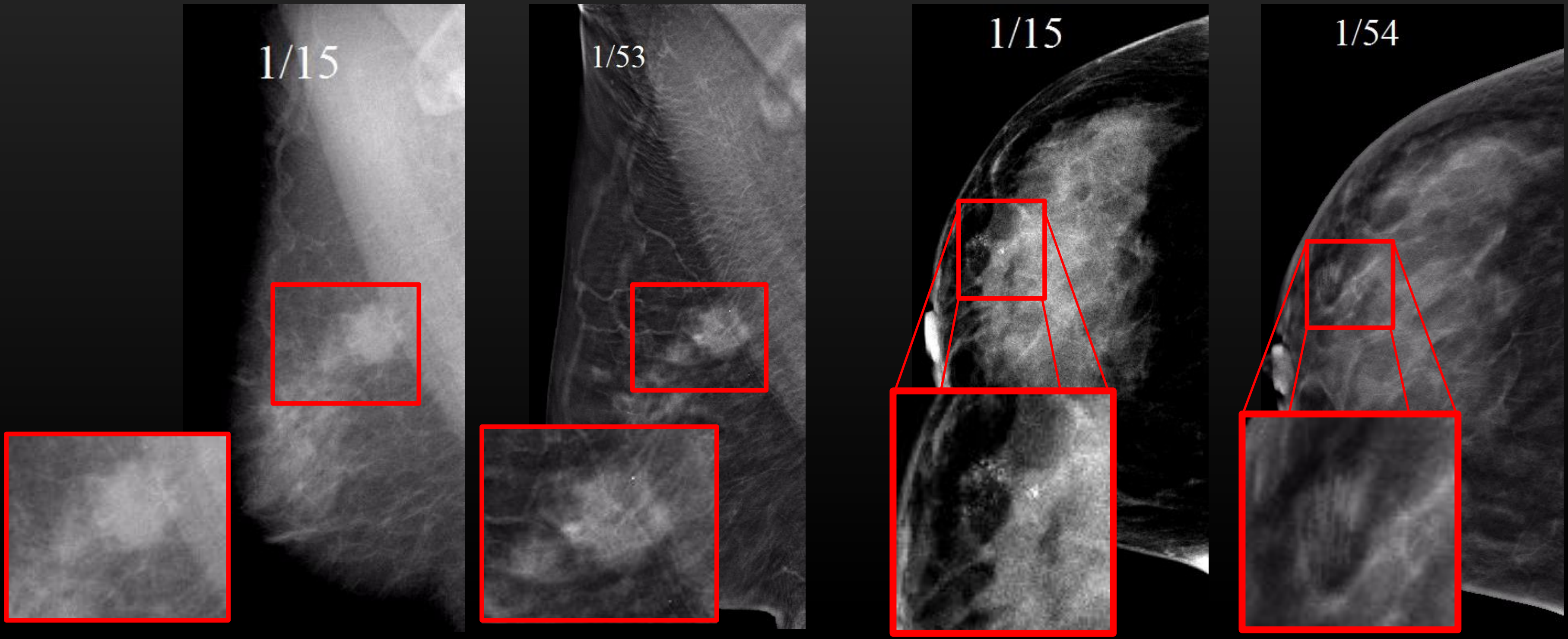
From Hologic Selenia Dimensions 3D System Sponsor Executive Summary

- ✓ The DBT in combination with digital mammography is approved by the Food and Drug Administration (FDA)[1)]

1) US Food and Drug Administration. Selenia Dimensions 3D System— P080003, Feb., 11, 2011.

Image pattern of DBT reconstructed slices and projection views

- **More data and information**
  - projection views (PVs) + reconstructed slices (RSs) :

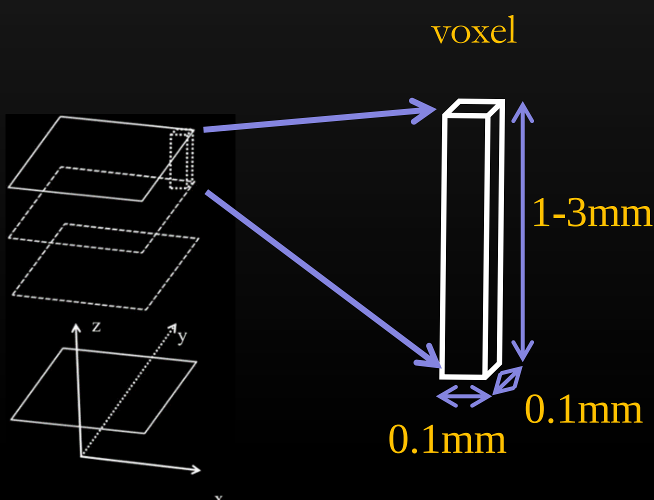


Mass on PVs   Mass on RSs   MC on PVs   MC on RSs

Limitations of DBT

- ❖ **PV images are noisy due to the low dose imaging**

- ❖ **RS images have reconstruction artifact (blur)**
  - Due to the limited angular range of projection views, different voxel size



DBT reconstructed slices

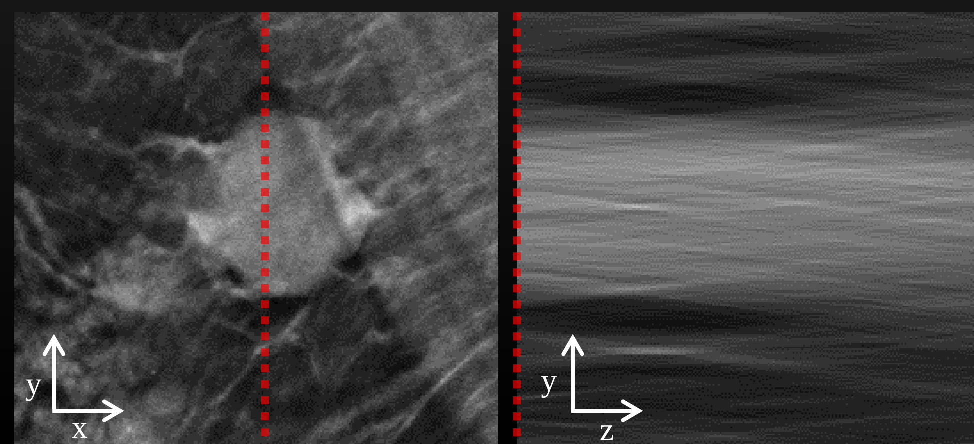
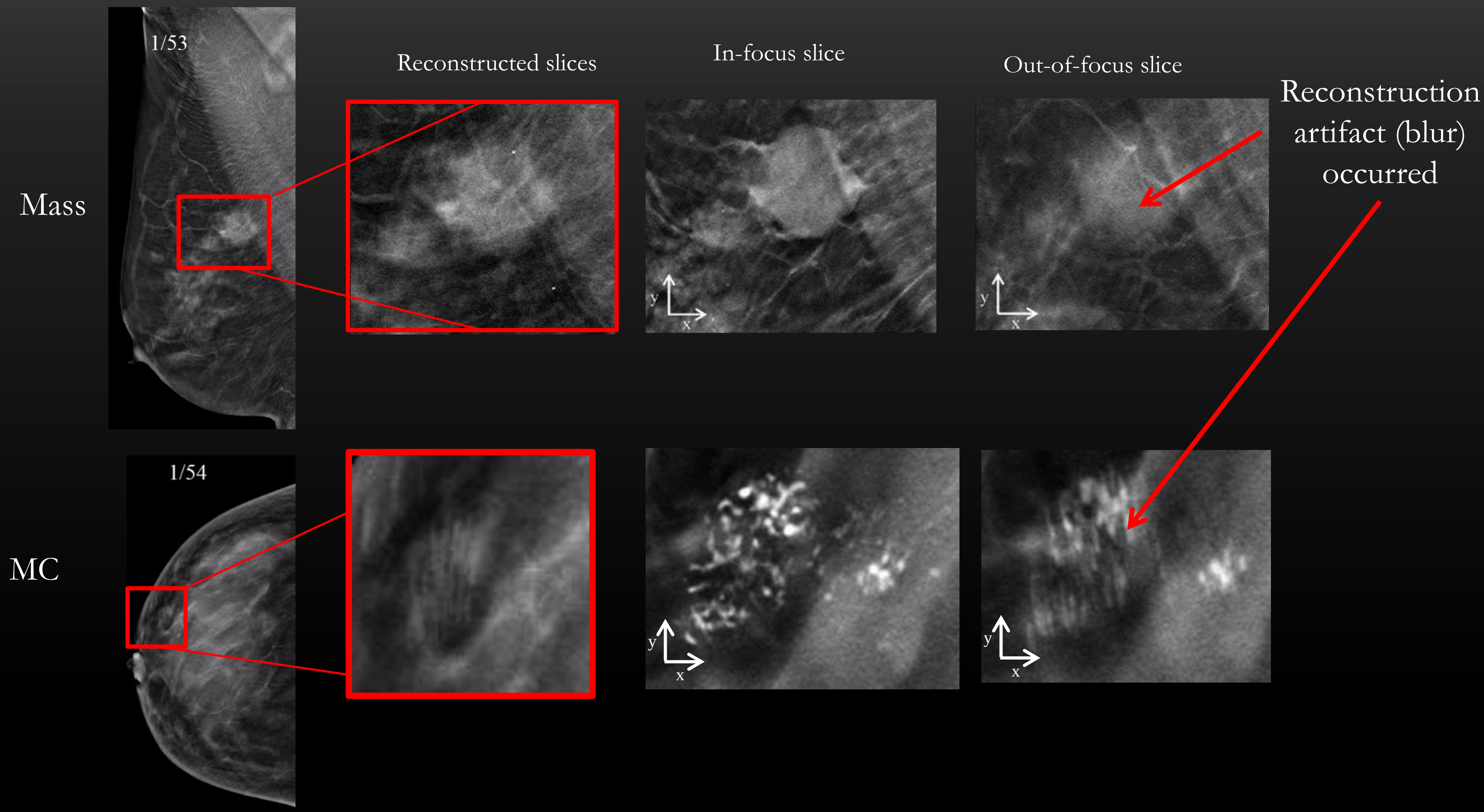


Image resolution is highly different between XY plane and YZ or XZ plane

Limitations of DBT

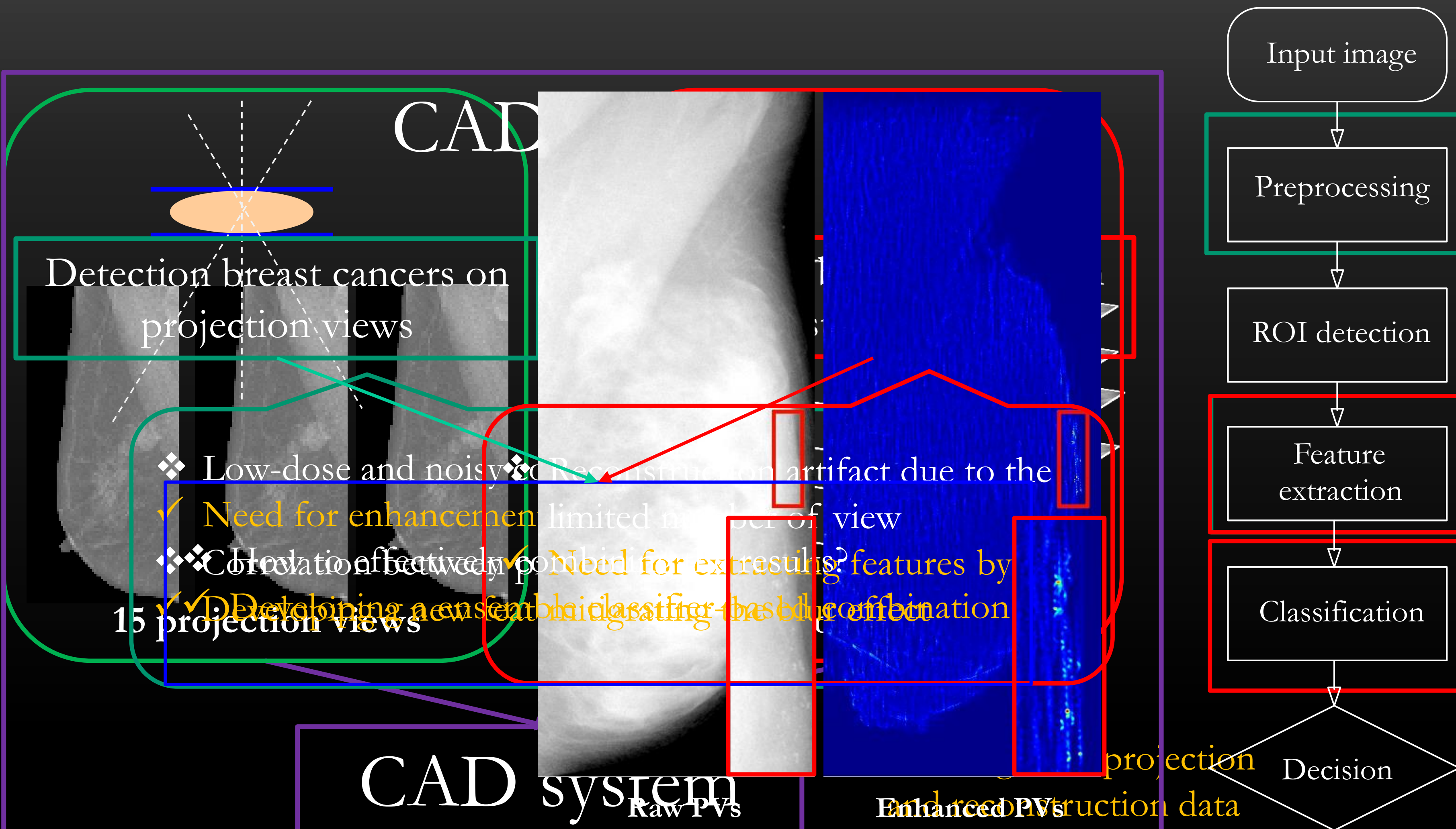
❖ Reconstruction artifact (blur)



S. T. Kim, D. H. Kim, **Y. M. Ro**, "Breast mass detection using slice conspicuity in 3D reconstructed digital breast volumes," Physics in Medicine and Biology, 2014.

High performance DBT CAD developed by IVY lab

❖ Novelty : limitations reduction and maximum use of information from both PV and RS



W.J. Baddar, D. H. Kim, E.J. Kim, **Y. M. Ro**, "Utilizing digital breast tomosynthesis projection views correlation for microcalcification enhancement for detection purposes," to be presented at SPIE MI, 2015

Blur-free mass feature extraction for DBT CAD

- Mass feature extraction in in-focus slice found automatically
  - Finding in-focus slice automatically (Object borders in the in-focus plane are sharp)
  - Feature extraction in estimated in-focus slice

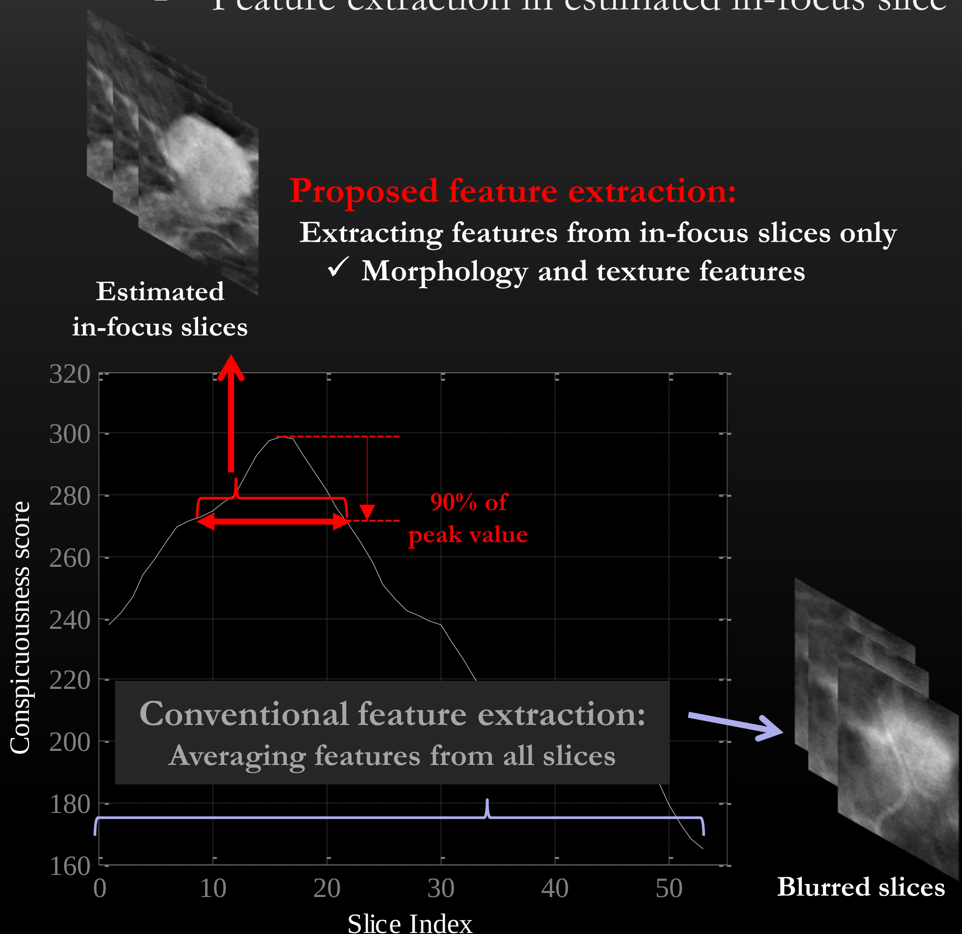
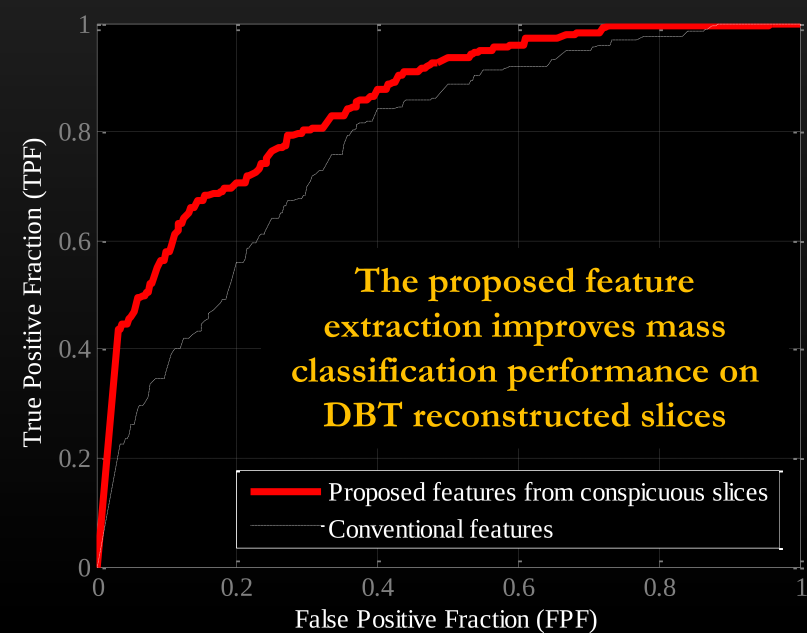


Illustration for new feature extraction in in-focus slices



Classification ROC curve

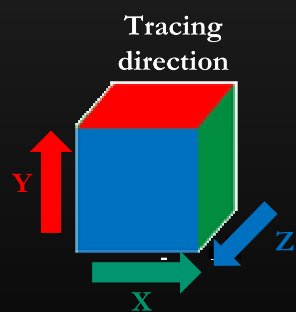
S. T. Kim, D. H. Kim, Y. M. Ro, "Breast mass detection using slice conspicuity in 3D reconstructed digital breast volumes," Physics in Medicine and Biology, 2014.

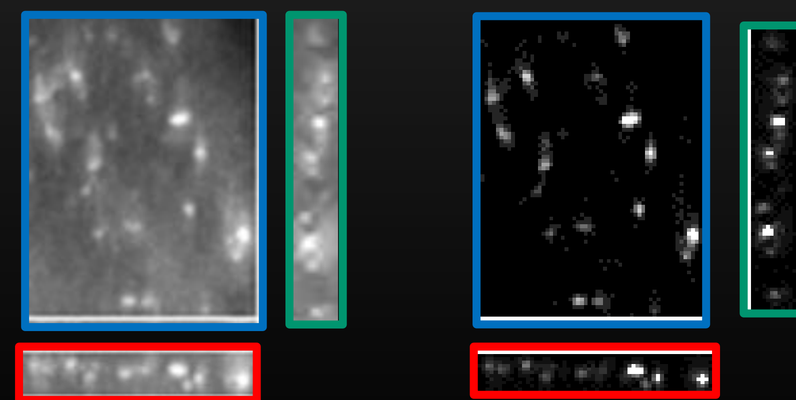
New MC feature extraction for DBT CAD

❖ MC feature extraction from maximum value tracing images

- Improves MC visibility compared with blurred MCs, thus feature can better describe MCs
- The MC cluster structure can be easily shown and kept intact in the traced images

VOI from the DBT volume



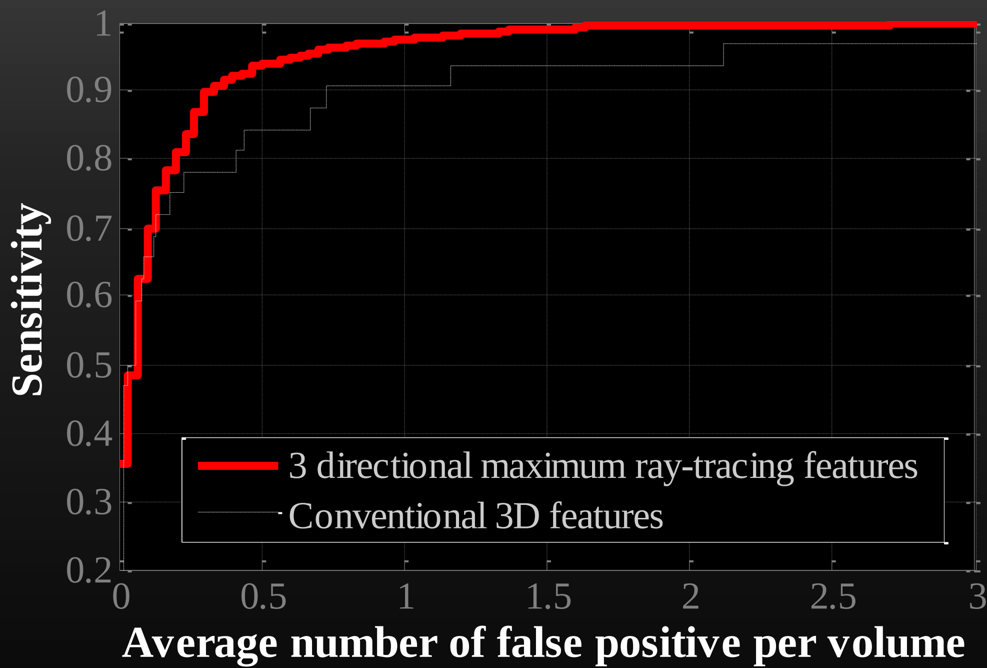


Tracing the VOI of the DBT in 3 Dimensions

Extracting texture features describing relation with surrounding tissue

Extracting texture features describing MC cluster structure and distribution

New MC feature extraction for DBT CAD



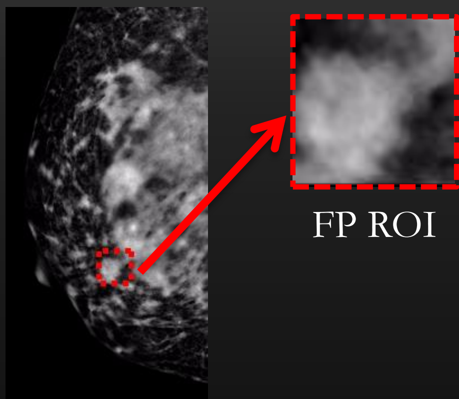
Classification FROC curve

The proposed feature extraction improves MC classification performance on DBT reconstructed slices

E.J. Kim, D.H. Kim, E.S. Cha, and **Y.M. Ro**. "Improvement of subtle microcalcifications detection in DBT slices." In Biomedical and Health Informatics (BHI), 2014 IEEE-EMBS International Conference on, pp. 322-325. IEEE, 2014.

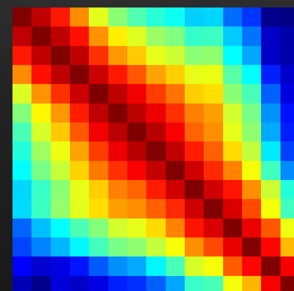
New mass feature in PVs

- ❖ **Consistent similarity between projection views: Utilizing different characteristics of masses and FPs on PVs**

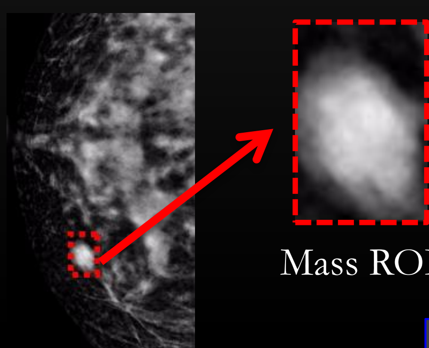


FP ROI

Mass enhanced PVs

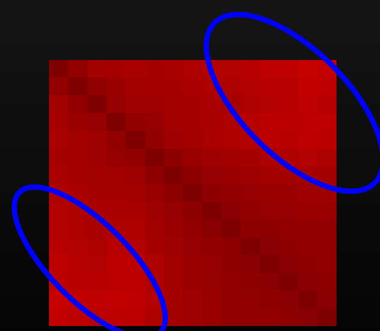


Inter-view similarity of FP



Mass ROI

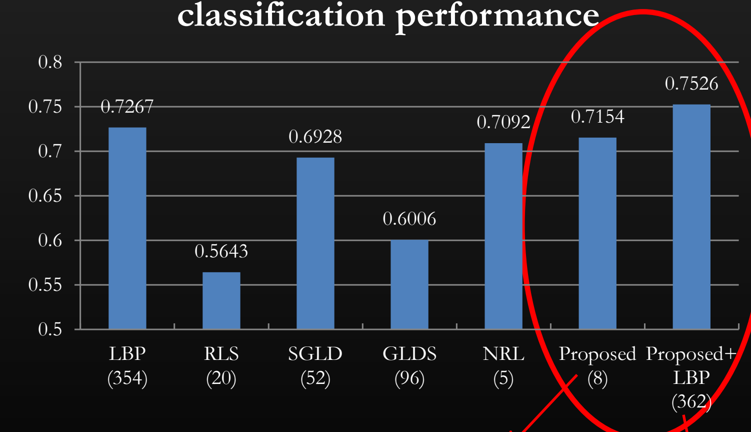
Mass enhanced PVs



Inter-view similarity of mass

Mass shows higher inter-view similarities compared to FP

Area under the RUC curve (AUC)
*** Higher AUC means better classification performance**



Proposed feature shows high AUC with small number of features

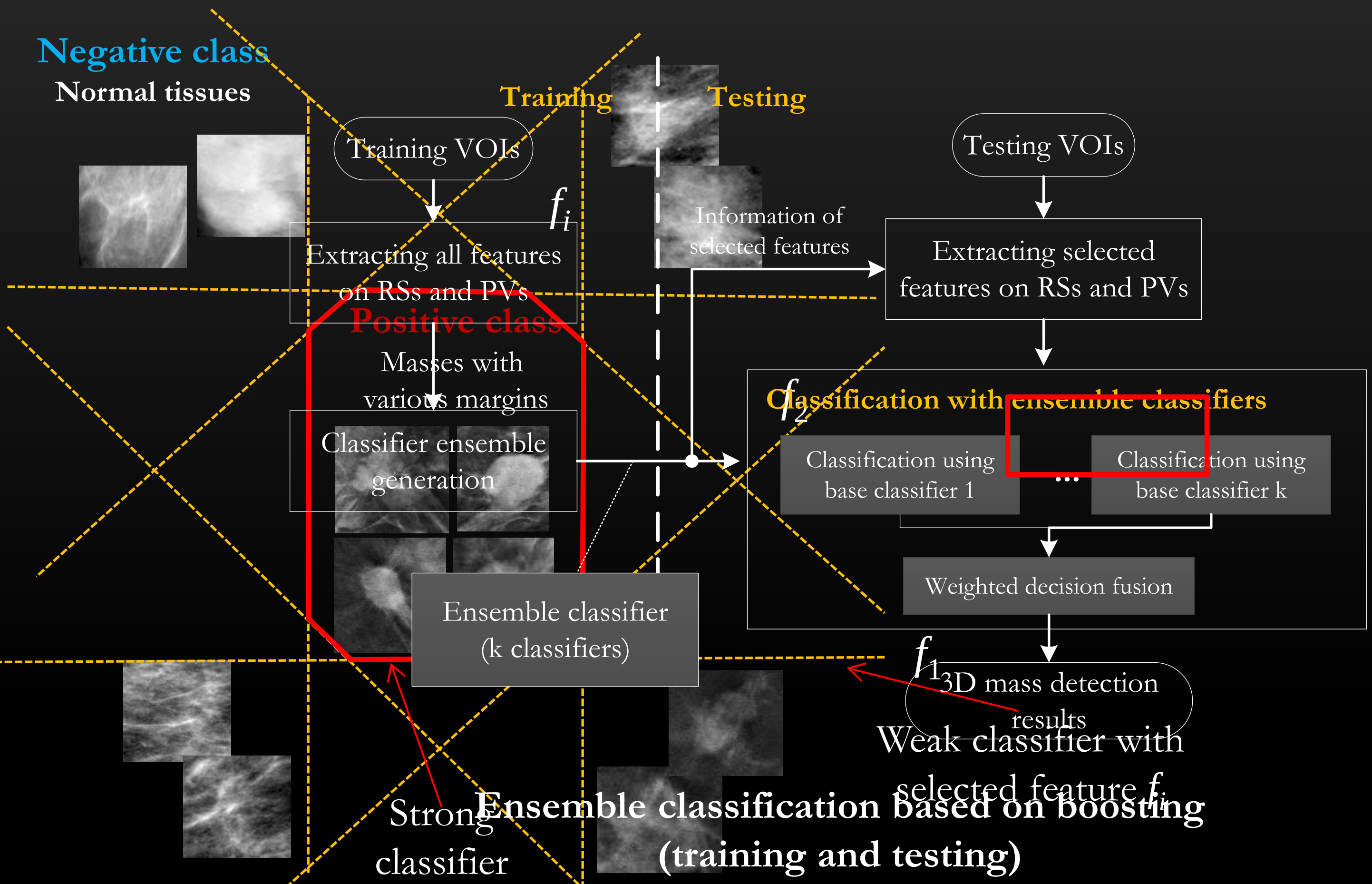
The concatenated features (multi-resolution LBP features [1] and proposed features) further improved AUC performance

D. H. Kim, S. T. Kim, **Y. M. Ro**, "Feature extraction from inter-view similarity of DBT projection views," SPIE Medical Imaging, 2015

[1] J. Y. Choi and **Y. M. Ro**, "Multiresolution local binary pattern texture analysis combined with variable selection for application to false positive reduction in computer-aided detection of breast masses on mammograms," Physics in Medicine and Biology, vol 57, no. 2, pp. 7029-7052, October 2012

Maximum use of information from both PV and RS for High performance DBT CAD lab

- **New ensemble classification for mass CAD fusing RSs and PVs**
  - Characteristics of lesion are different in RSs and PVs
  - Multiple classifiers with feature selection is needed to classify complex data

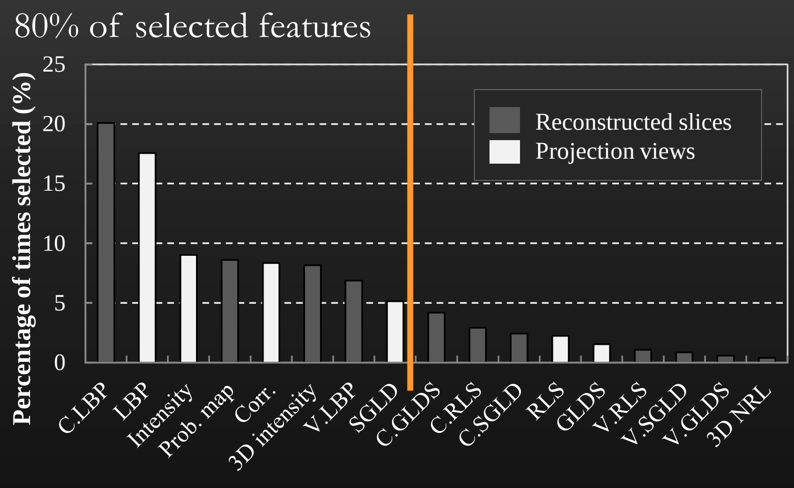


Ensemble classification based on boosting (training and testing)

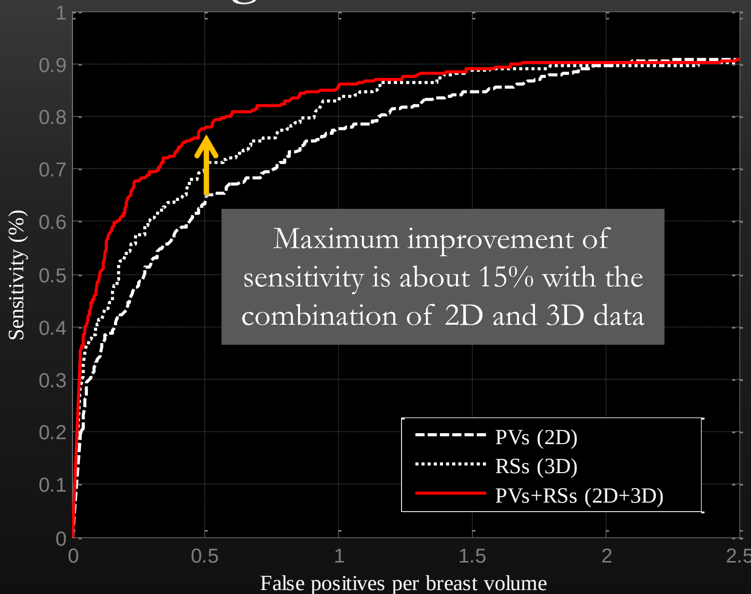
D. H. Kim, S. T. Kim, **Y. M. Ro**, "Improving mass detection using combined features from projection views and reconstructed volume of DBT and boosting based classification with feature selection," submitted to Physics in Medicine and Biology, 2014

Maximum use of information from both PV and RS for High performance DBT CAD lab

❖ New ensemble classification for mass CAD fusing RSs and PVs

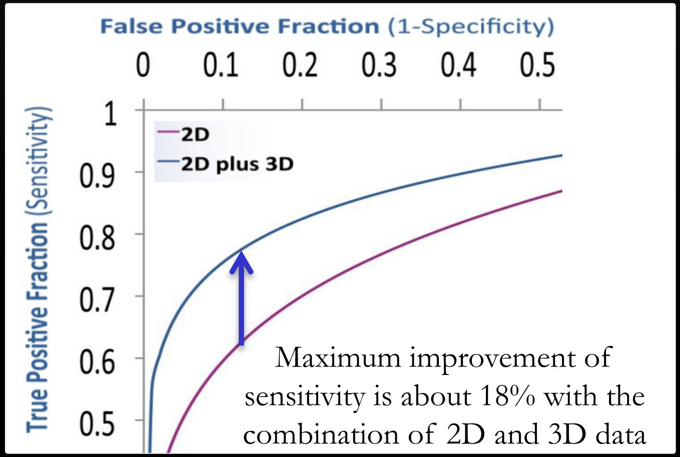


Selected features in the boosting framework



Classification FROC curve

Dominant features are extracted from both on PVs and RSs

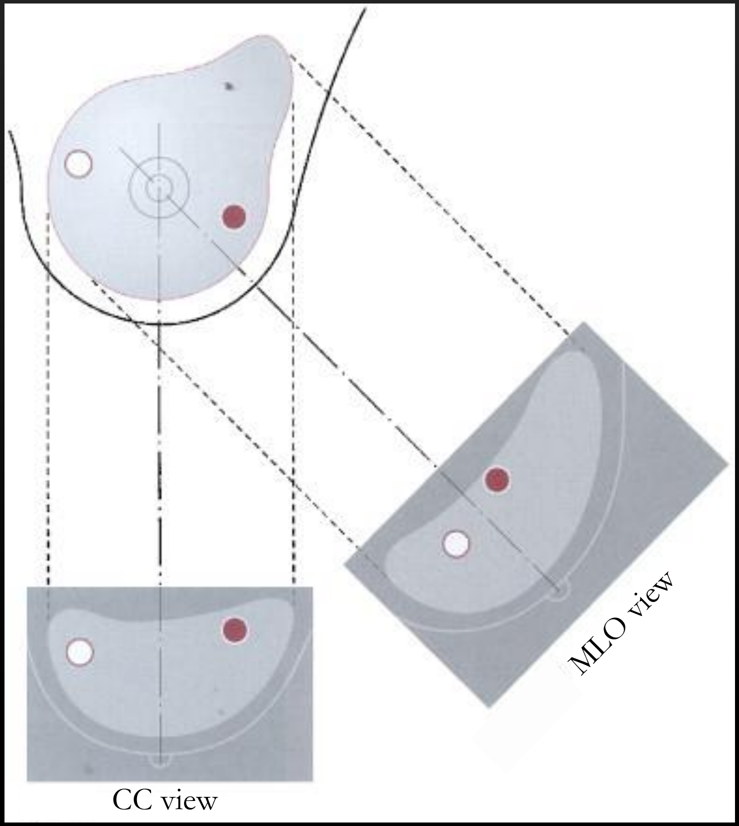


ROC curves for clinical study

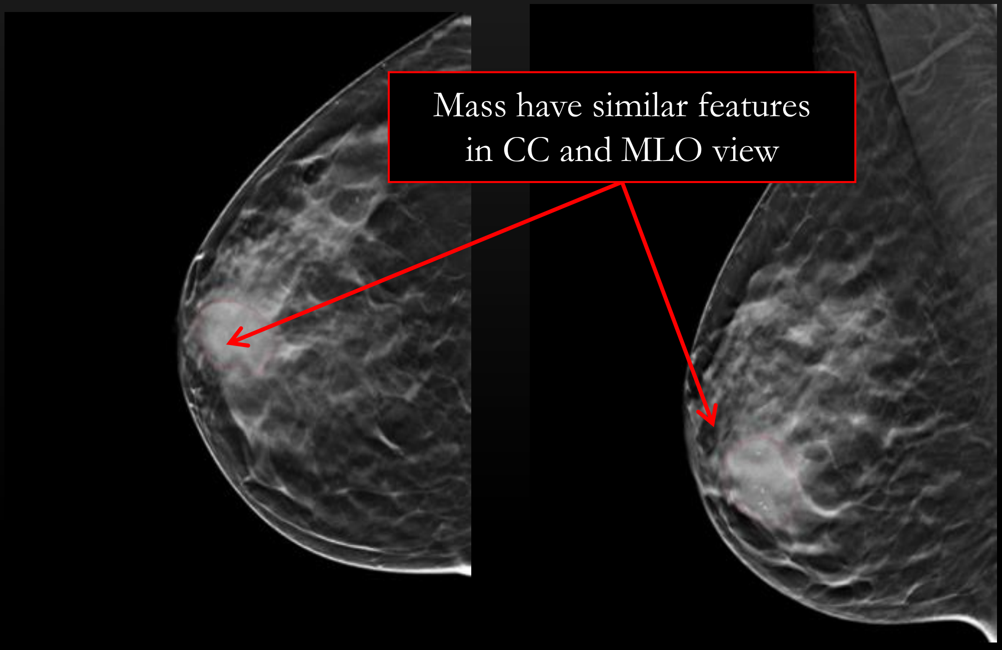
D. H. Kim, S. T. Kim, **Y. M. Ro**, "Improving mass detection using combined features from projection views and reconstructed volume of DBT and boosting based classification with feature selection," submitted to Physics in Medicine and Biology, 2014

Multiview analysis

- **Clinical practice**
  - Radiologists analyze the ipsilateral views to detect cancers and to reduce FPs
  - Matching corresponding regions in the ipsilateral DBT views is important



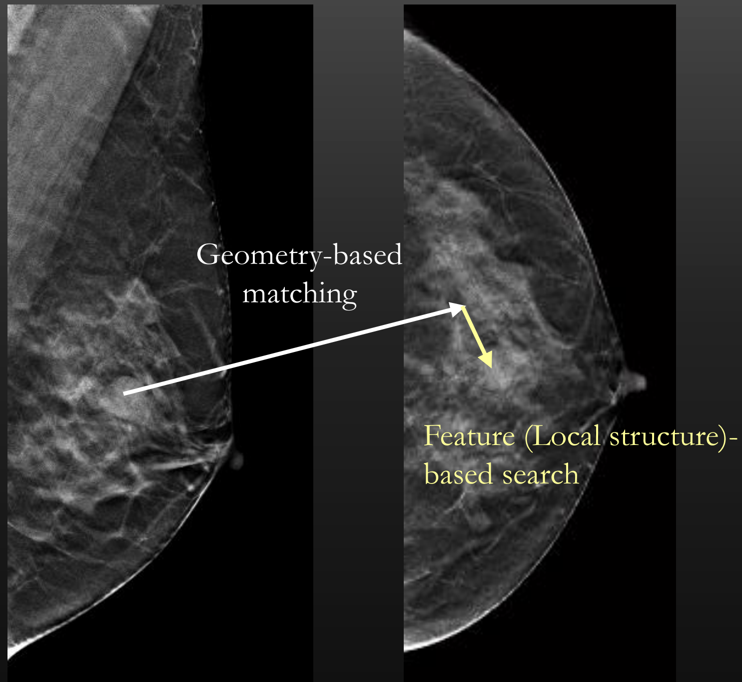
Ipsilateral views



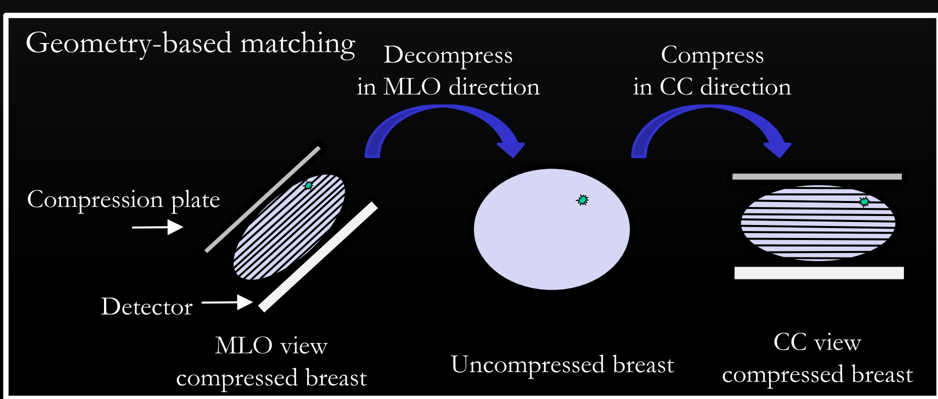
Right CC view RSs

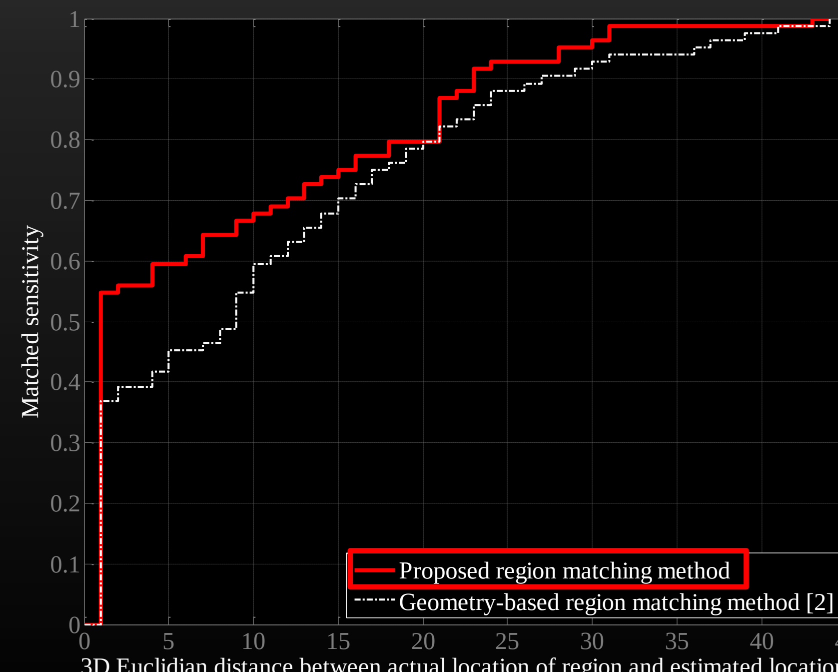
Right MLO view RSs

Multiview analysis: Region matching in ipsilateral DBT views



Left MLO view RSs | Left CC view RSs





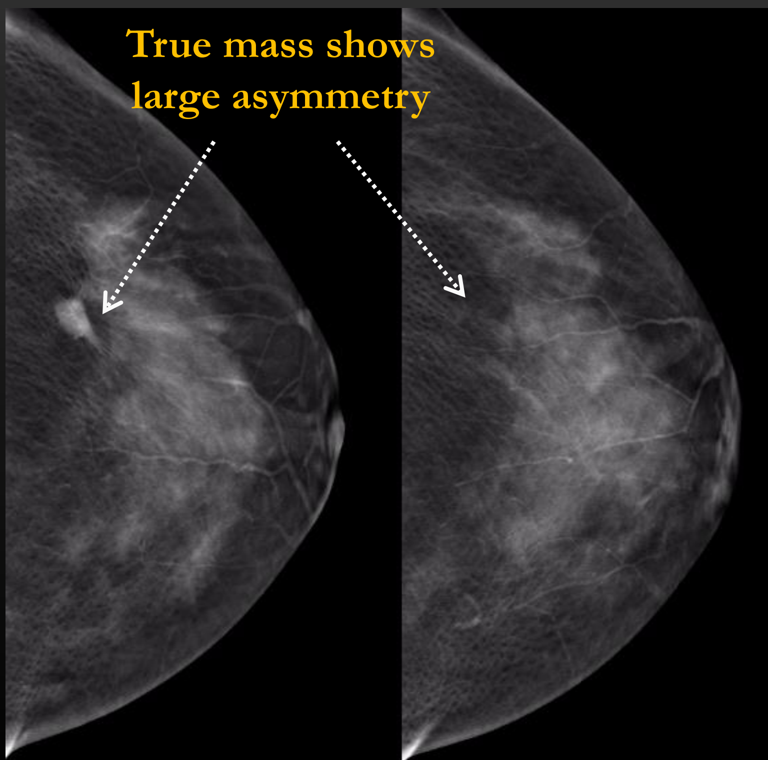
Accuracy of the proposed region matching method and breast compression model-based region matching method

S. T. Kim, D. H. Kim, D. J. Ji, and Y. M. Ro, "Region Matching based on local structure information in ipsilateral digital breast tomosynthesis views," to be presented at IEEE ICIP, 2015

[2] G. Van Schie, C. Tanner, P. Snoeren, M. Samulski, K. Leifland, M. G. Wallis, et al., "Correlating locations in ipsilateral breast tomosynthesis views using an analytical hemispherical compression model," Physics in Medicine and Biology, vol. 56, p. 4715, 2011.

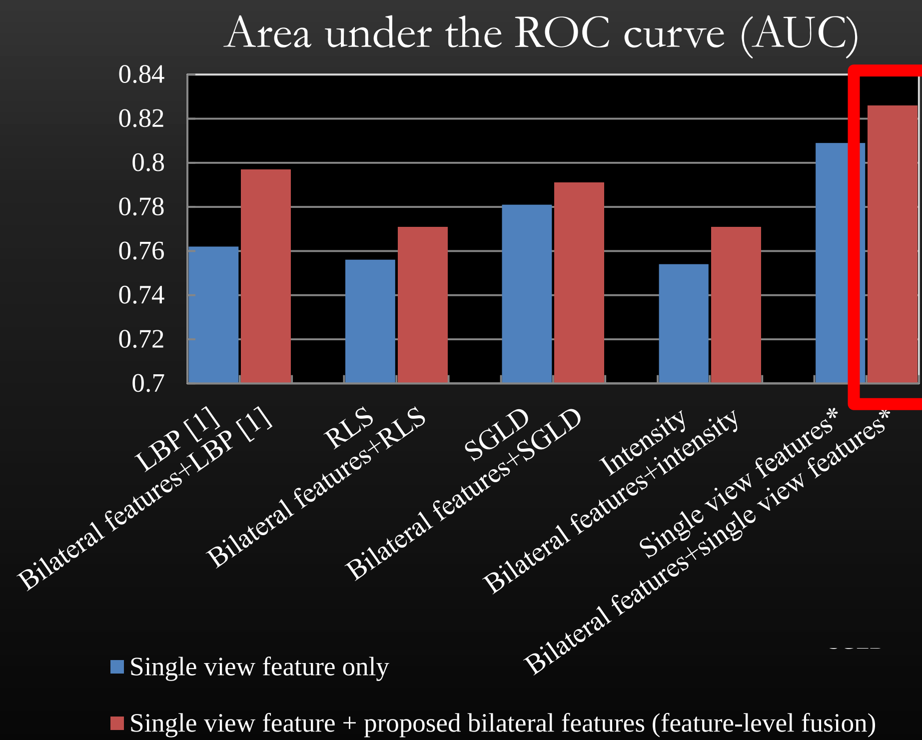
Multiview analysis: New bilateral mass features in DBT RSs

❖ **Bilateral features from asymmetric density of masses between the left and right breasts**



Left CC view RSs with detected VOIs

Right CC view RSs with corresponding VOIs
(VOIs in left breast are transformed into right breast)



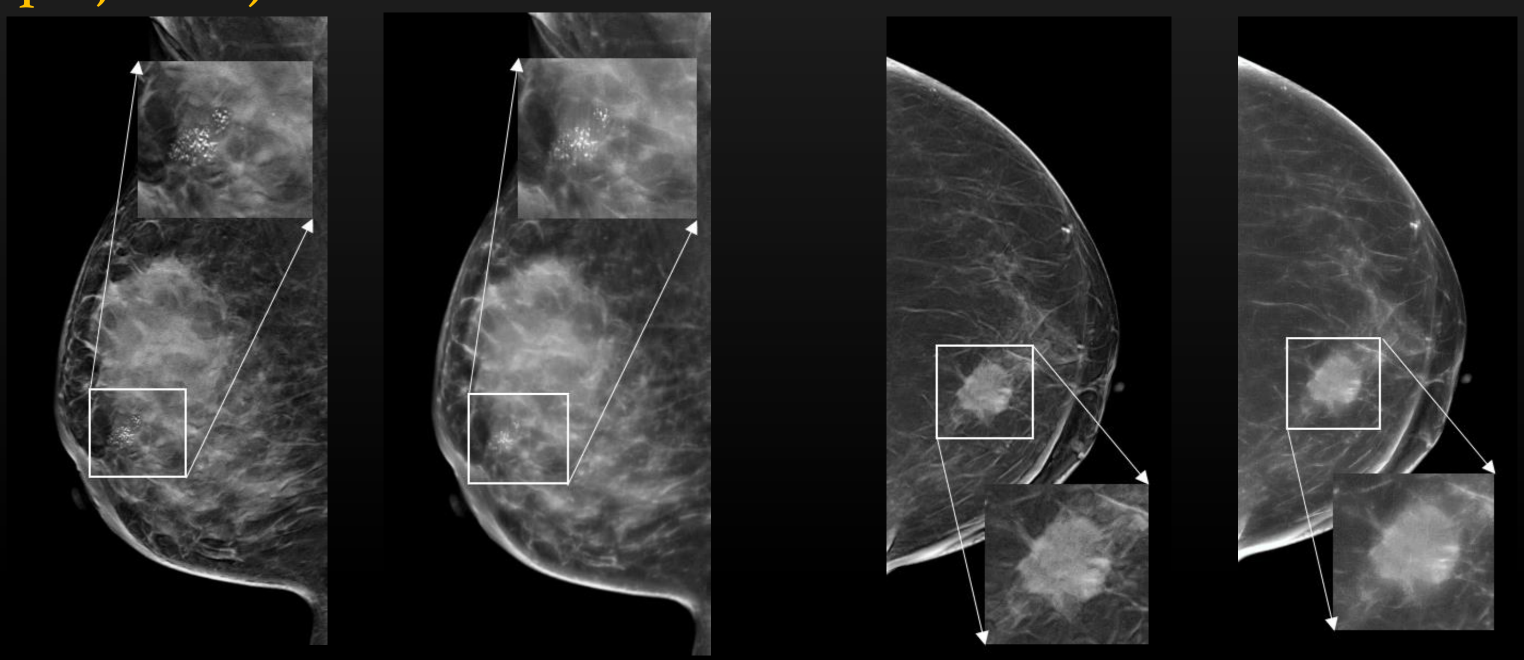
* 'Single view features*' denotes an augmented feature vector that concatenates LBP, RLS, SGLD, intensity features by feature-level fusion

Proposed bilateral features improve overall AUCs compared to the AUCs with single-view feature only

D. H. Kim, S. T. Kim, Wissam J. Baddar, **Y. M. Ro**, "Feature extraction from bilateral dissimilarity in DBT reconstructed volume," to be presented at IEEE ICIP, 2015
[1] J. Y. Choi and **Y. M. Ro**, "Multiresolution local binary pattern texture analysis combined with variable selection for application to false positive reduction in computer-aided detection of breast masses on mammograms," Physics in Medicine and Biology, vol 57, no. 2, pp. 7029-7052, October 2012

Synthetic mammogram: Solution for dose rate

- Currently, as approved by the U. S. Food and Drug Administrator (FDA), DBT should be used in combination with DM [3].
- Drawback of combination with DM
  - DBT with DM accompanies doubled dose rate and shooting time in screening.
- **Solution: Synthetic mammogram (Proposed method: Conspicuity-based projection)**



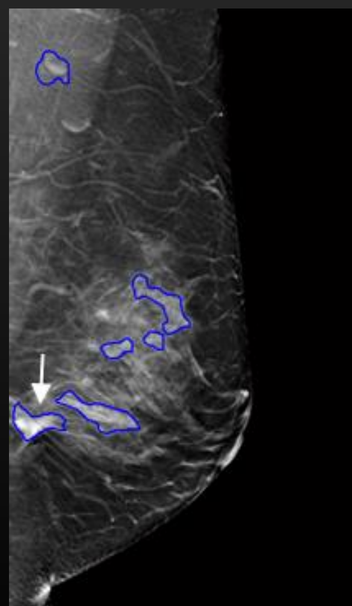
Proposed method | Maximum intensity projection[4] | Proposed method | Maximum intensity projection[4]

S. T. Kim, D. H. Kim, and Y. M. Ro, "Generation of Conspicuity-improved Synthetic Image from Digital Breast Tomosynthesis" Intenrational Conference on Digital Signal Processing, 2014
[3] M. L. Zuley, et al., Radiology, pp. 131530, 2014.
[4] F. Diekmann et al., "Thick slices from tomosynthesis data sets: phantom study for the evaluation of different algoruthms," Journal of Digital Imaging, 2009.

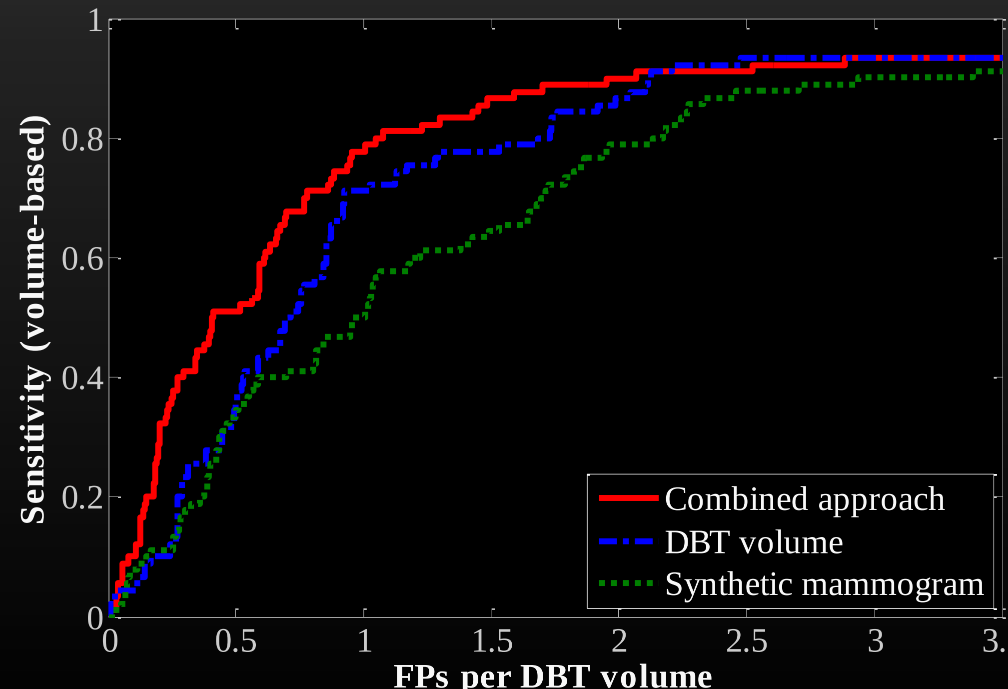
Combination CAD using DBT and synthetic mammogram

❖ Complementary information between synthetic mammogram and DBT RSs

DBT RSs



Synthetic mammogram



DBT and synthetic mammogram have complementary information

S. T. Kim, D. H. Kim, and Y. M. Ro, "Combination of conspicuity improved synthetic mammograms and digital breast tomosynthesis: a promising approach for mass detection" SPIE Medical Imaging, 2015

❖ KAIST DBT CAD System Video

ivylab.kaist.ac.kr

Publications (CAD)

1. Dae Hoe Kim, Seong Tae Kim, Wissam J. Baddarm, and Yong Man Ro, "Feature extraction from bilateral dissimilarity in DBT reconstructed volume," IEEE International Conference on Image Processing (accepted), 2015.
2. Seong Tae Kim, Dae Hoe Kim, Dong Jin Ji, and Yong Man Ro, "Region matching based on local structure information in ipsilateral digital breast tomosynthesis views," IEEE International Conference on Image Processing (accepted), 2015.
3. Seong Tae Kim, Dae Hoe Kim, and Yong Man Ro, "Combination of conspicuity improved synthetic mammograms and digital breast tomosynthesis: A promising approach for mass detection," *SPIE Medical Imaging*, 2015
4. Dae Hoe Kim, Seong Tae Kim, and Yong Man Ro, "Feature extraction from inter-view similarity of DBT projection views," *SPIE Medical Imaging*, 2015
5. Wissam J. Baddar, Eun Joon Kim, Dae Hoe Kim and Yong Man Ro, "Utilizing digital breast tomosynthesis projection views correlation for microcalcification enhancement for detection purposes," *SPIE Medical Imaging*, 2015
6. Seong Tae Kim, Dae Hoe Kim, and Yong Man Ro, "Breast mass detection using slice conspicuity in 3D reconstructed digital breast volumes," *Physics in Medicine and Biology*, vol. 59, pp. 5003-5023, 2014.
7. Dae Hoe Kim, Jae Young Choi, Yong Man Ro, "Region based stellate features combined with variable selection using AdaBoost learning in mammographic computer-aided detection," *Computers in Biology and Medicine (in press)*, Available online 27 September 2014.
8. Jae Young Choi, Dae Hoe Kim, Konstantinos N. Plataniotis, and Young Man Ro, "Computer-aided detection (CAD) of breast masses in mammography: Combined detection and ensemble classification," *Physics in Medicine and Biology*, vol. 59, pp. 3697-3719, Jun 2014.

10. Seong Tae Kim, Dae Hoe Kim, and Yong Man Ro, "Generation of conspicuity-improved synthetic image from digital breast tomosynthesis," *International Conference on Digital Signal Processing*, 2014
11. Seong Tae Kim, Dae Hoe Kim, Eun Suk Cha, and Yong Man Ro, "Mass detection based on pooled mass probability map of 3D reconstructed slices in digital breast tomosynthesis," *IEEE-EMBS BHI*, 2014
12. Eun Joon Kim, Dae Hoe Kim, Eun Suk Cha, and Yong Man Ro, "Improvement of subtle microcalcifications detection in DBT slices," *IEEE-EMBS BHI*, 2014
13. Wissam J. Baddar, Dae Hoe Kim, and Yong Man Ro, "Breast tissue removal for enhancing microcalcification cluster detection in mammograms," *IEEE-EMBS BHI*, 2014
14. Dae Hoe Kim, Seung Hyun Lee, and Yong Man Ro, "Mass type-specific sparse representation for mass classification in computer-aided detection on mammography," *Biomedical Engineering Online,* 12(Suppl 1):S3, 2013.
15. Seung Hyun Lee, Dae Hoe Kim, and Yong Man Ro, "Mass type-specific sparse representation for mass classification in computer-aided detection on mammograms," *IEEE EMBC Workshop*, 2013
16. Seung Hyun Lee, Dae Hoe Kim, Jae Young Choi, and Yong Man Ro, "Improving positive predictive value in Computer-aided Diagnosis using mammographic mass and microcalcification confidence score fusion based on co-location information," *SPIE Medical Imaging*, 2013
17. Dae Hoe Kim, Jae Young Choi, and Yong Man Ro, "Boosting framework for mammographic mass classification with combination of CC and MLO view information," *SPIE Medical Imaging*, 2013
18. Jae Young Choi, and Yong Man Ro, "Multiresolution local binary pattern texture analysis combined with variable selection for application to false positive reduction in computer-aided detection of breast masses on mammograms," *Physics in Medicine and Biology*, vol 57, no. 2, pp. 7029-7052, Oct. 2012.

20. Seung Hyun Lee, Dae Hoe Kim, Won Yong Eom, and Yong Man Ro, "Investigating the sparse representation of breast mass features in digital mammography," *IFMIA,* 2012
21. Wonyong Eom, Wesley De Neve, and Yong Man Ro, "Sparse feature analysis for detection of clustered microcalcifications in mammogram images," *IFMIA,* 2012
22. Dae Hoe Kim, Jae Young Choi, and Yong Man Ro, "Region Based Stellate Features for Classification of Mammographic Spiculated Lesions in Computer-Aided Detection," *IEEE ICIP*, 2012
23. Dae Hoe Kim, Jae Young Choi, and Yong Man Ro, "A Novel Mammographic Mass Detection Approach to Combining Supervised and Unsupervised Detection Algorithms," *IEEE ICIP*, 2012
24. Jae Young Choi, Dae Hoe Kim, Konstantinos N. Plataniotis, and Yong Man Ro, "Combining Multiple Feature Representations and AdaBo.ost Ensemble Learning for Reducing False-positive Detections in Computer-Aided Detection of Masses on Mammograms," *IEEE EMBC*, 2012
25. Jae Young Choi, Dae Hoe Kim, Seon Hyeong Choi, and Yong Man Ro, "Multiresolution Local Binary Pattern Texture Analysis for False Positive Reduction in Computerized Detection of Breast Masses on Mammograms," *SPIE Medical Imaging,* 2012
26. Dae Hoe Kim, Jae Young Choi, Seon Hyeong Choi, Yong Man Ro, "Mammographic Enhancement with Combining Local Statistical Measures and Sliding Band Filter for Improved Mass Segmentation in Mammograms," *SPIE Medical Imaging,* 2012
27. Jae Young Choi, Dae Hoe Kim, and Yong Man Ro, "Combining Multiresolution Local Binary Pattern Texture Analysis and Variable Selection Strategy Applied to Computer-Aided Detection of Breast Masses on Mammograms," *IEEE-EMBS BHI,* 2012
28. Jae Young Choi, Dae Hoe Kim, Yong Man Ro, "Computer-Aided Detection of Breast Masses on Mammograms Using Region-Based Feature Analysis," *MITA*, 2011
29. Sunil Cho, Sung Ho Jin, Yong Man Ro, Sung Min Kim, "Microcalcification Detection System in Digital Mammogram using Two-Layer SVM," *SPIE Medical Imaging,* 2008

30. Ju Won Kwon, Yong Man Ro, Sung Min Kin, "Improvement of SVM based Microcalcification Detection," *Asian Forum on Medical Imaging, 2007*
31. Hokyung Kang, Yong Man Ro, Sung Min Kim, "A microcalcification detection using adaptive contrast enhancement on wavelet transform and neural network," *IEICE Trans. on Information & Systems*,Vol.E89-D, pp.1280-1287 March, 2006
32. Ju Won Kwon, Hokyoung Kang, Yong Man Ro, Sung Min Kim, "A Microcalcification Detection Using Multi-Layer Support Vector Machine in Korean Digital Mammogram" *World Congress on Medical Physics and Biomedical Engineering (WC 2006)*
33. Ho-Kyung Kang, Nguyen N. Thanh, Sung-Min Kim, and Yong Man Ro, "Robust contrast enhancement for microcalcification in mammography," *LNCS* 3045, pp. 602-610, July 2004
34. Ho-Kyung Kang, Sung-Min Kim, Nguyen N. Thanh,Yong Man Ro, and Won-Ha Kim, "Adaptive microcalcification detection in computer aided diagnosis," *LNCS* 3039, pp. 1110-1117, June 2004
35. Jeong Hyun Yoon, Yong Man Ro, "Enhancement of the contrast in mammographic imges using the homomorphic filter method," *IEICE Trans. on Information & Systems*,Vol.E85-D, pp.298-333, January 2002
36. Jeong Hyun Yoon, Yong Man Ro, "Contrast Enhancement of Mammography Image using Homomorphic Filter in Wavelet Domain," *International Workshop on Digital Mammography (IWDM)*, 2000