

On Compression Model for Integrative Analysis of Different View Breast Xrays

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Shinichi Tokumoto **

Shinichi Hirai***

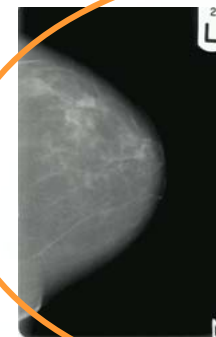
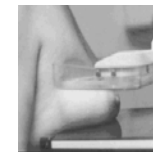
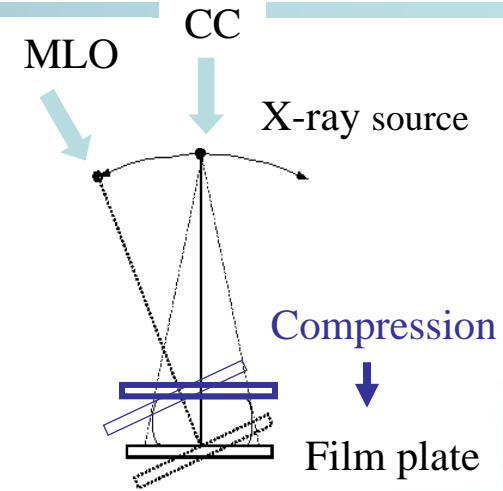
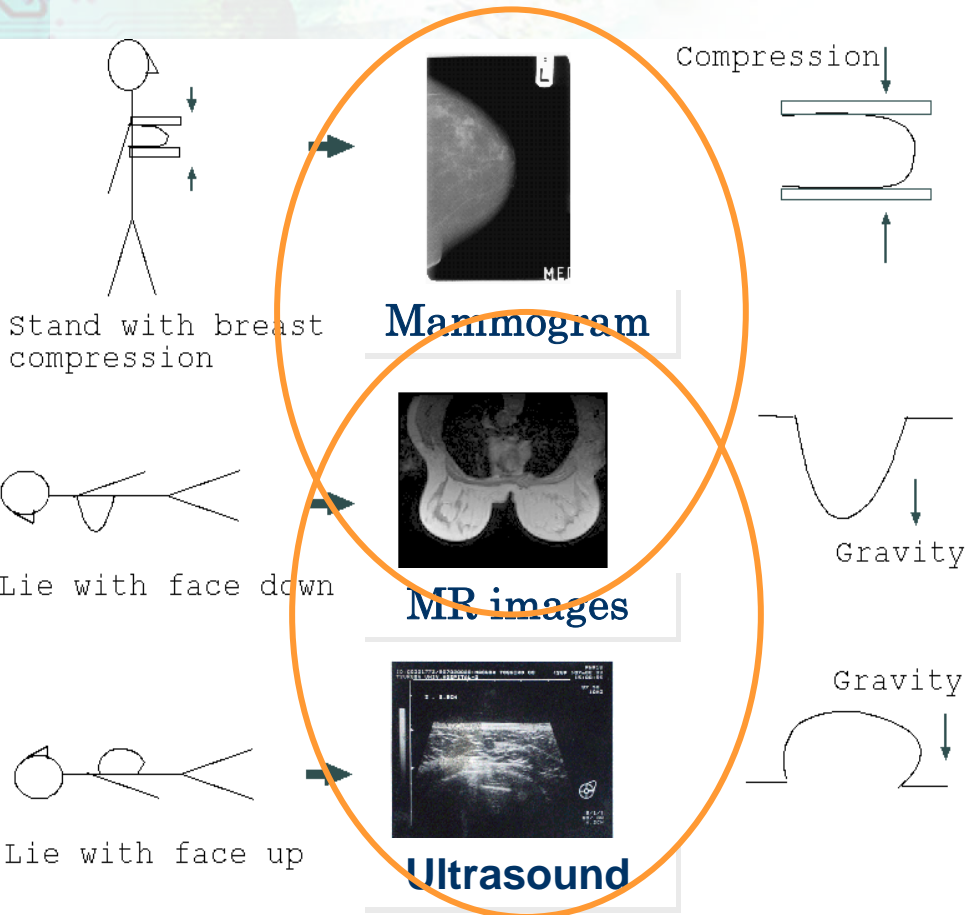
*Information Technology Research Institute,
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**System Division, Industrial Technology Center of
Wakayama Prefecture

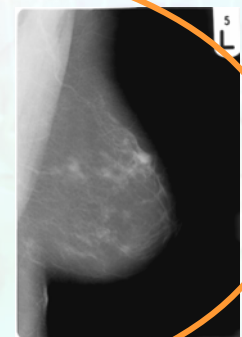
***Dept. Robotics, Ritsumeikan Univ.

Breast deformation in Medical procedures

Integrative Analysis → Breast registration



CC (Cranio-Caudal)



MLO (Medio-Lateral Oblique)

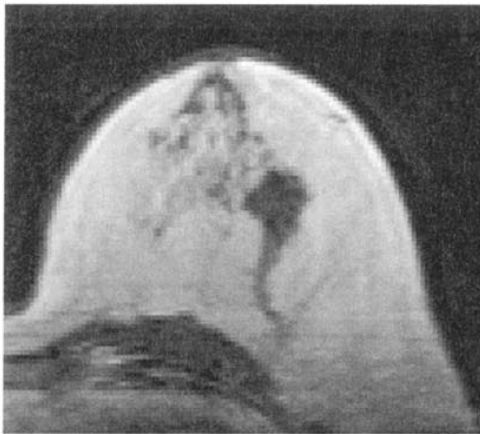
Brief review of breast registration considering its deformation

In the case of small deformation (ex. pre-post contrast with the same posture)

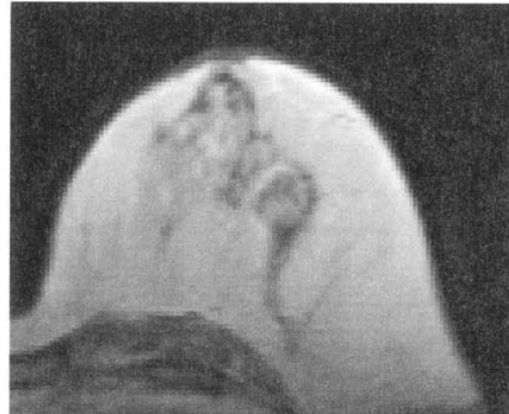
Image based registration

that nonrigidly deforms breast region so that the two images look similar as much as possible while keeping smooth deformation

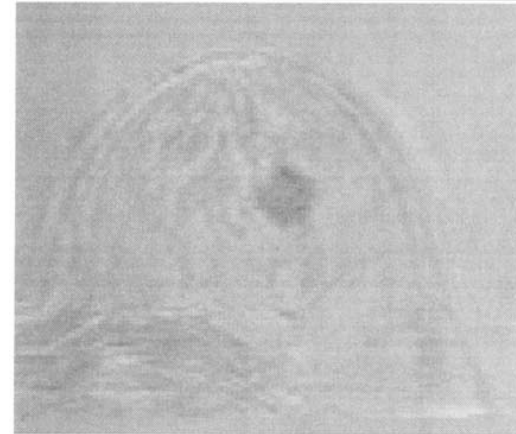
[Rueckert et. al. 99]



A) Before Contrast



B') After Contrast
with deformation



Subtraction (A-B')

From Rueckert et. al. :“Nonrigid Registration Using Free-Form Deformations:
Application to Breast MR Images” ,IEEE TMI 99, Vo; 18, No.8

Brief review of breast registration considering its deformation

In the case of small deformation (ex. pre-post contrast with the same posture)

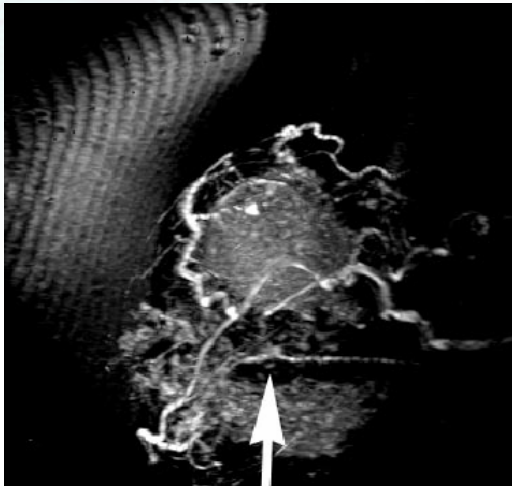
Image based registration

without consideration of physics

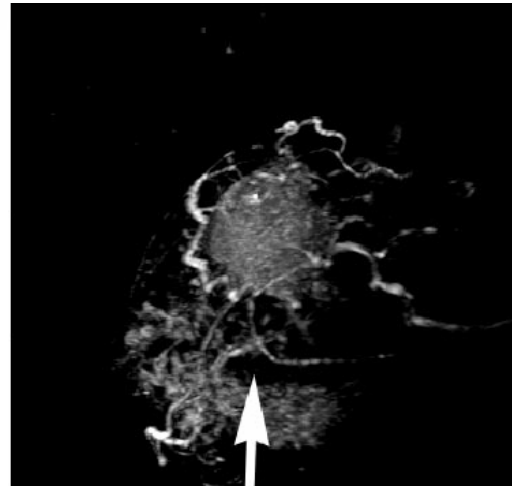


+ Volume preserving
constraints

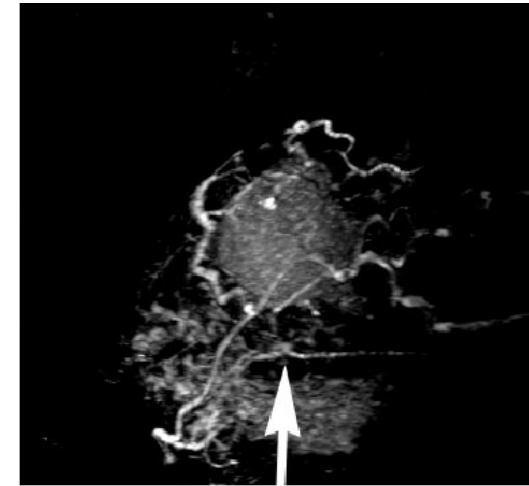
[Rohlfing et. al. 03]



Rigid registration



Nonrigid registration



Nonrigid registration with
volume constraint

From Rohlfing et. al. : "Volume-Preserving Nonrigid Registration of MR Breast Images Using Free-Form Deformation With an Incompressibility Constraint", IEEE TMI, Vol. 22; No.6, 2003.

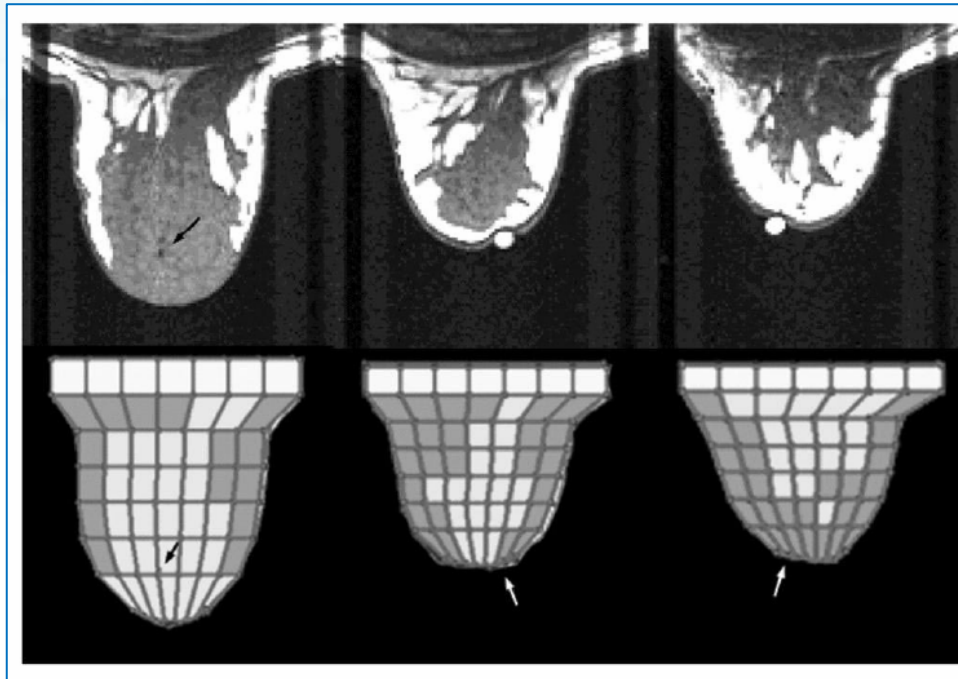
Brief review of breast registration considering its deformation

In the case of large deformation (ex. Multimodal image registration)

Physics based registration

[Liu et. al. 04]

FEM(Finite Element models)



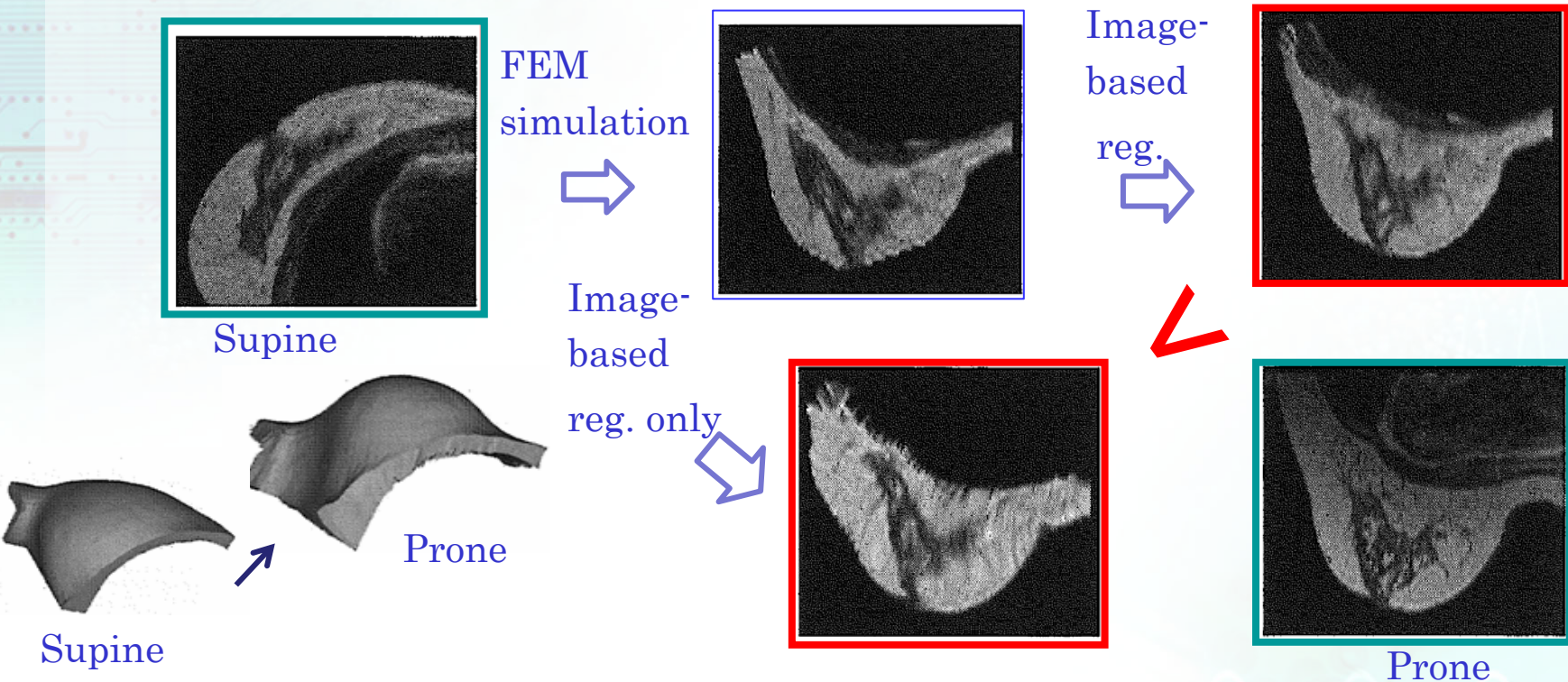
From Liu et. al. :“Methods for modeling and predicting mechanical deformation of the breast under external perturbations” , MIA, Vol. 6, 2004.

Brief review of breast registration considering its deformation

In the case of large deformation (ex. Multimodal image registration)

Physiscs based registration

[Carter et. al. 06]



From T.J. Carter, et.al : "Biomechanical Model Initialized Non-rigid Registration for Image-Guided Breast Surgery., In Proc. of MICCAI 2006 Workshop on Computational Biomechanics for Medicine, pp. 104.112, 2006.

Existing approaches of breast registration

- Images based registration + volume conservation

Input: Only two X-ray images of a breast

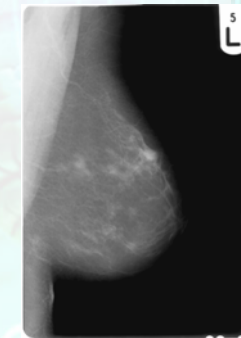
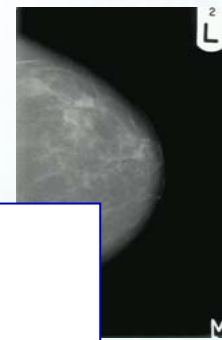
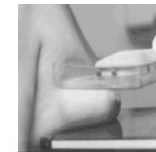
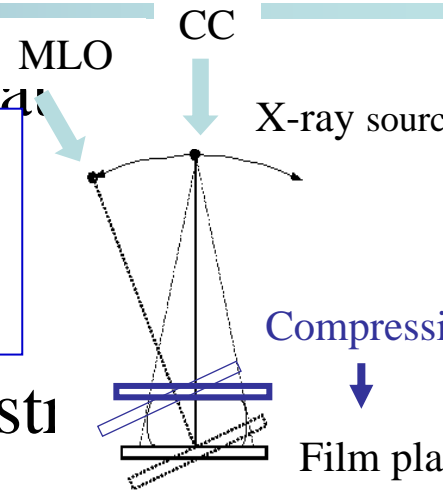
=> without detailed individual conditions

- FEM based registration (+ image based registration)

Requires

with detailed individual conditions
for large deformation

with details of external forces and
boundary conditions



Cranio-
Caudal)

MLO (Medio-
Lateral
Oblique

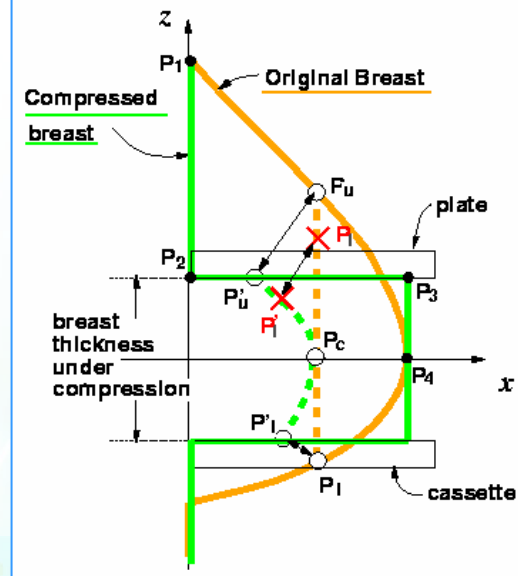
Strong compression

=> Large and complicated deformation

=> Large and complicated deformation

=> without detailed individual conditions

[Kita, Highnam and Brady 00]



Outline of Talk

1. Review of breast deformation in medical image analysis
2. Current compression model in our CAD (Computer Aided Diagnosis) system
3. Simulation of breast compression using a mechanical model
4. Inspection of internal deformation using devised phantom
5. Summary of observations
6. Conclusion

← Now

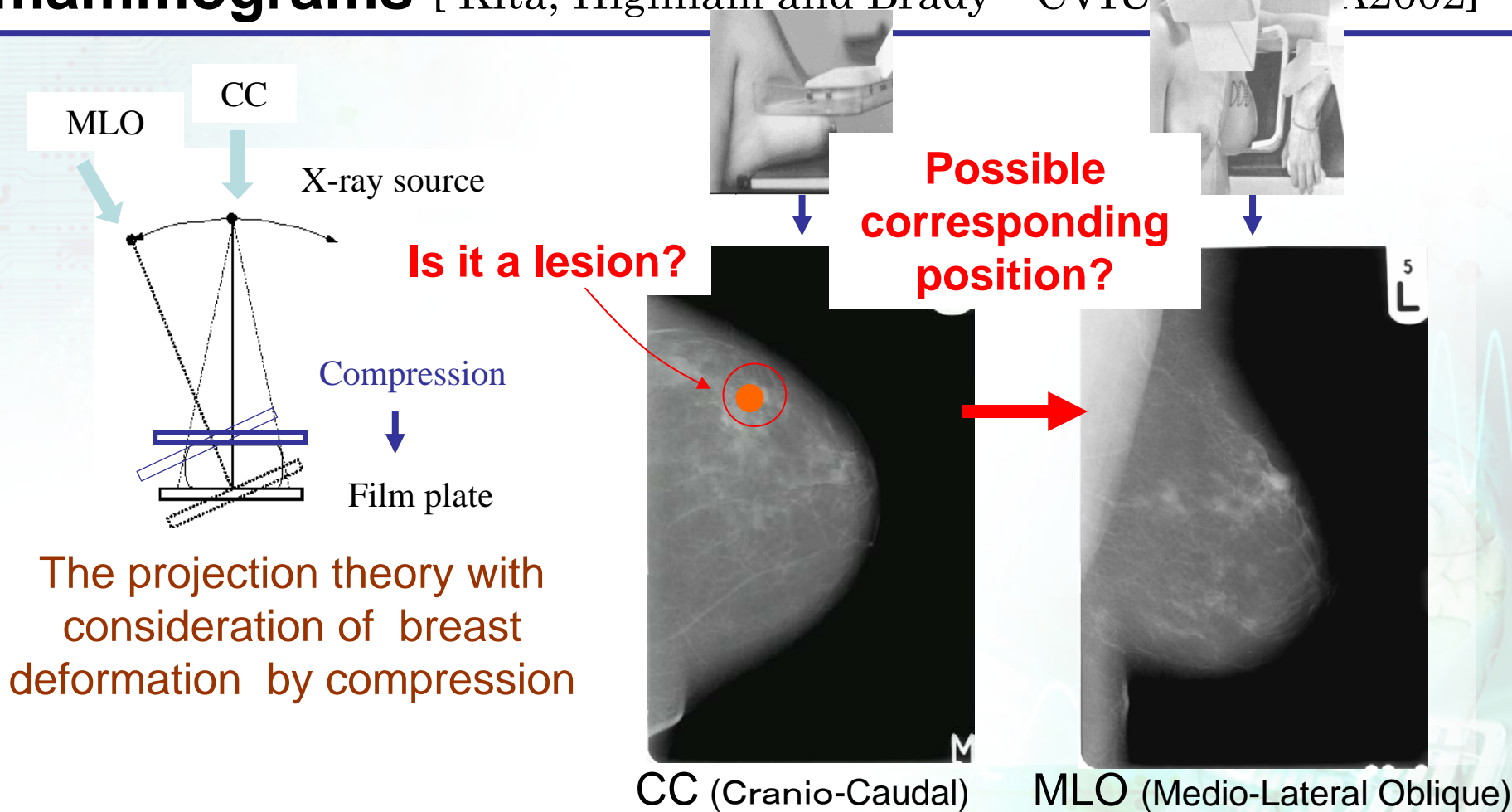


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A CAD system for integrative analysis of different view mammograms

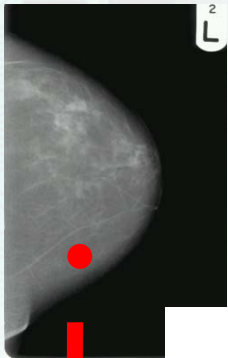
Mammography (breast x-ray)

A CAD system for the 3D location of lesions in mammograms [Kita, Highnam and Brady CVIU2000 MIA2002]

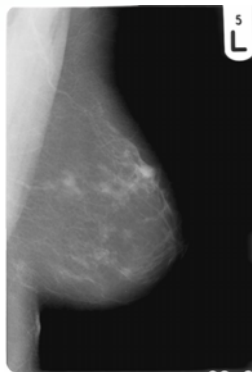


A CAD system for the 3D location of lesions in mammograms

Prediction of possible corresponding position in the other image



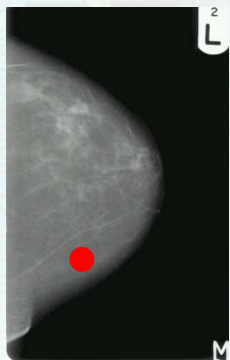
**Possible
corresponding
position?**



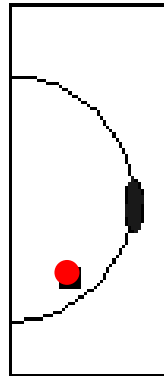
MLO

A CAD system for the 3D location of lesions in mammograms

Prediction of possible corresponding position in the other image



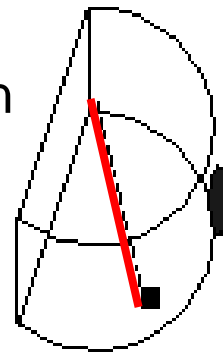
CC



Back
projection



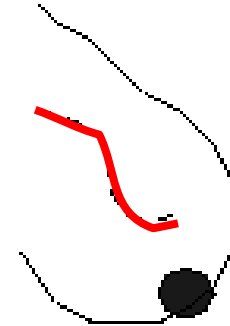
A

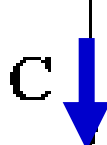


Uncom-
pression



B

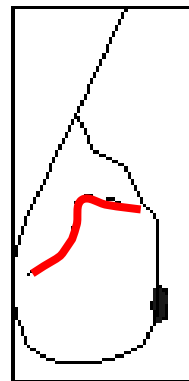



 Rotation
of X-ray
source

C



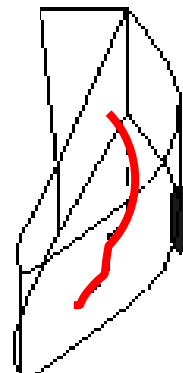
MLO



Projection



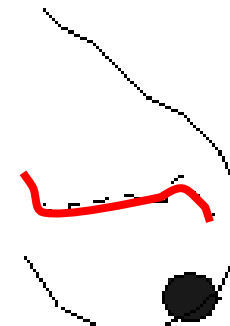
E



Com-
pression

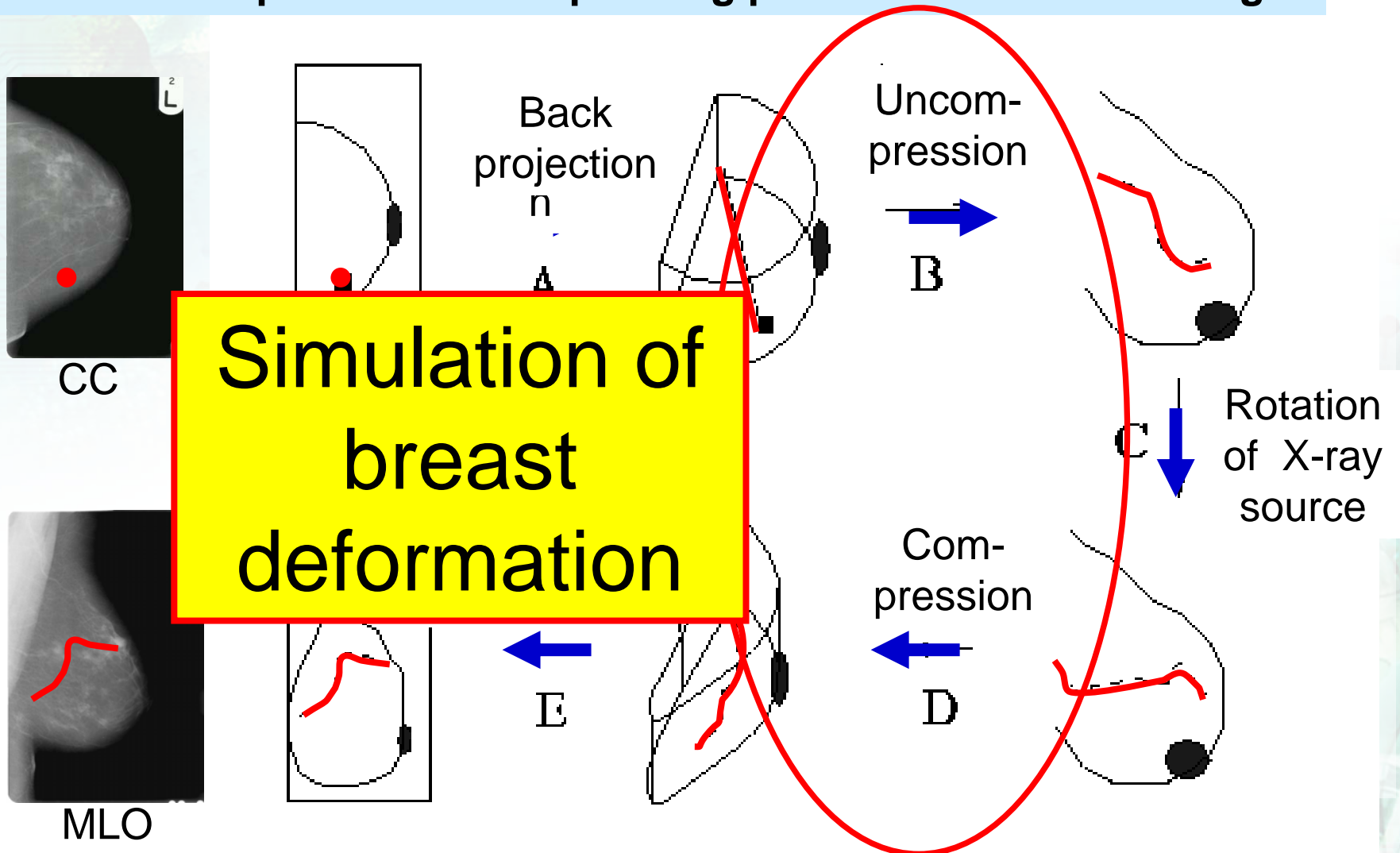


D

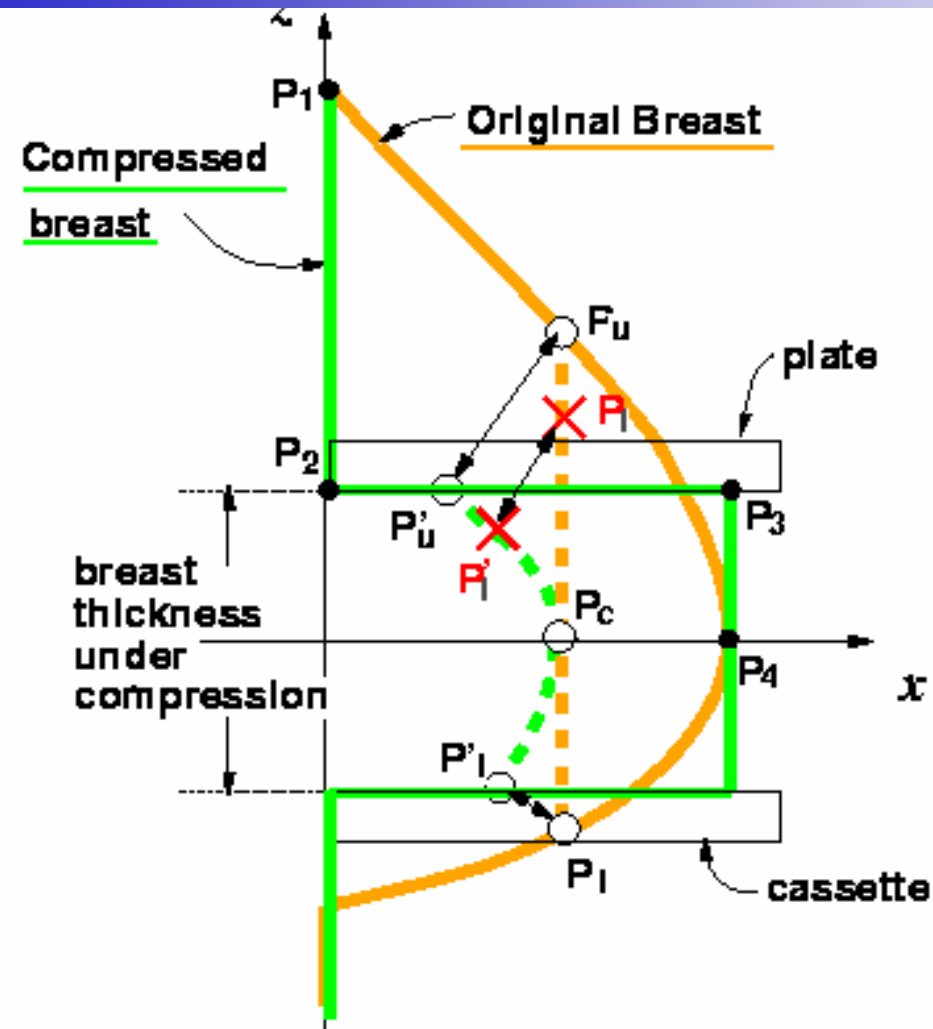


A CAD system for the 3D location of lesions in mammograms

Prediction of possible corresponding position in the other image



Simplified compression model



the cross-section for compression.

P \longleftrightarrow **P'**
Calculable

Approximation 2.

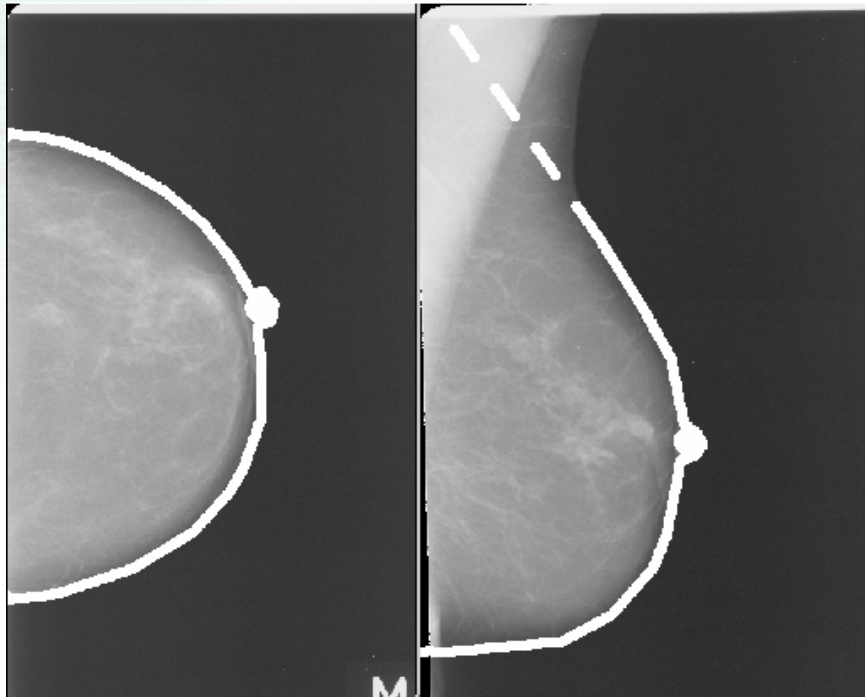
In the mid-plane
between the plate and
the cassette, there is
no deformation.

compression.



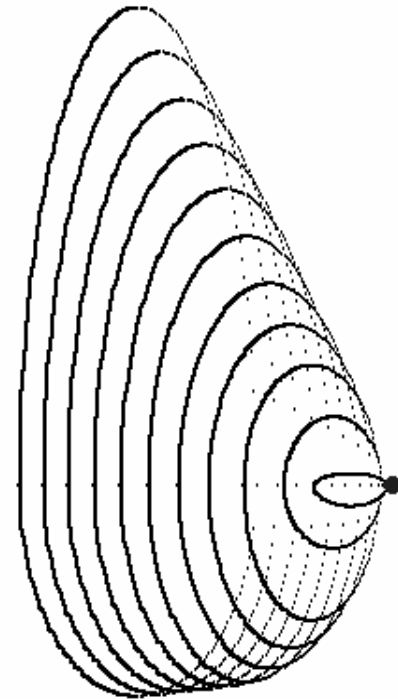
Approximate reconstruction of 3D breast shape

Approximated shape

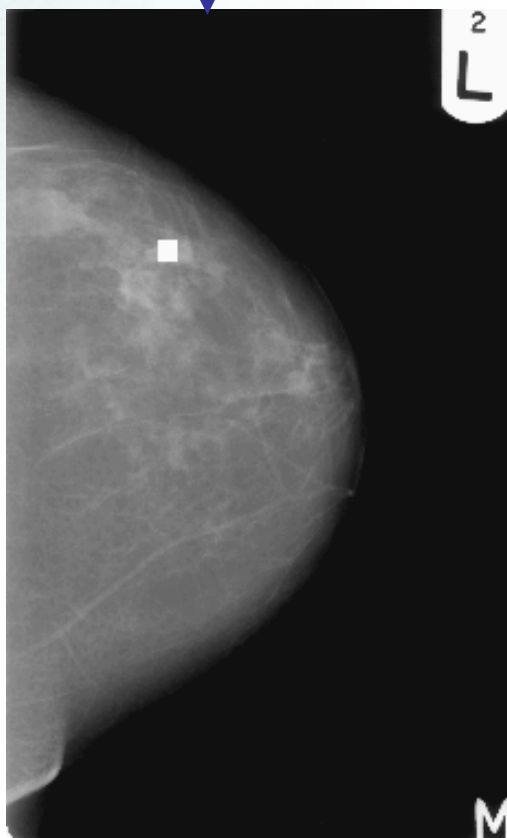
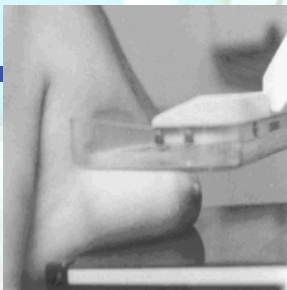


CC

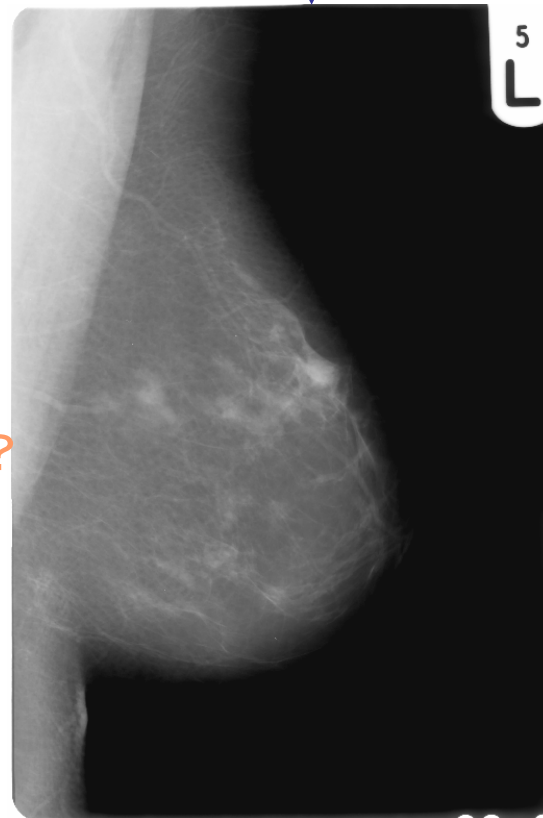
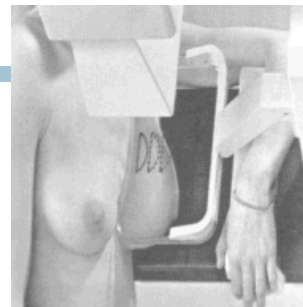
MLO



Example of results 1



CC



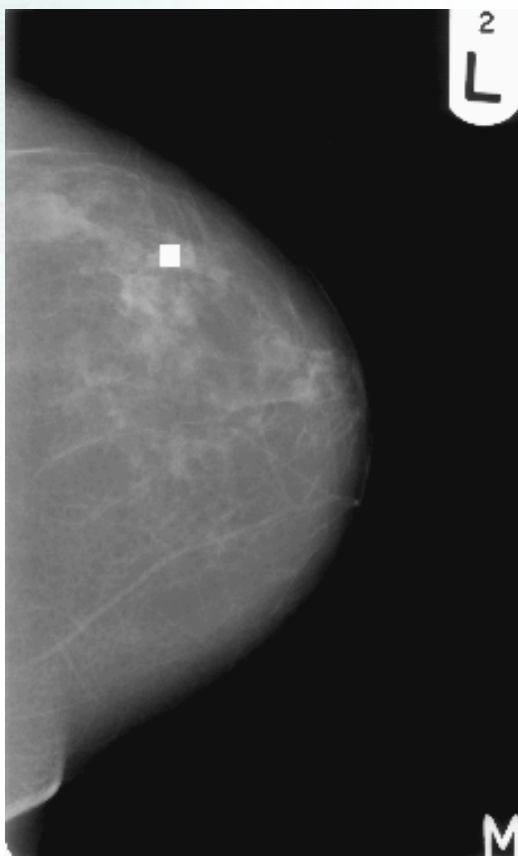
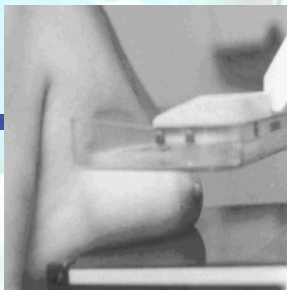
MLO



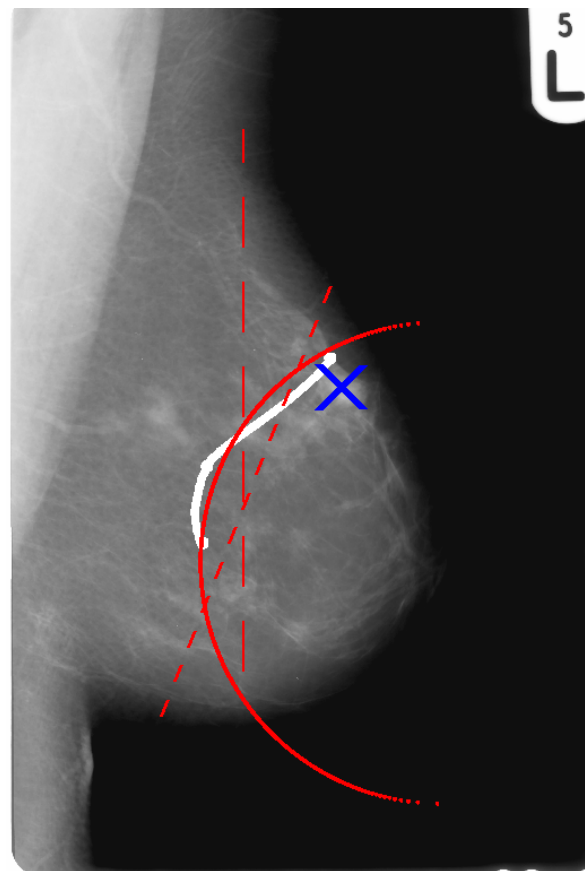
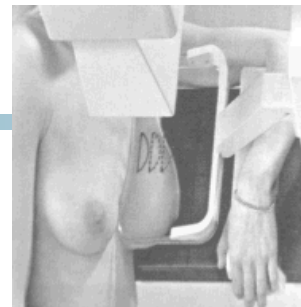
Where?



Example of results 1



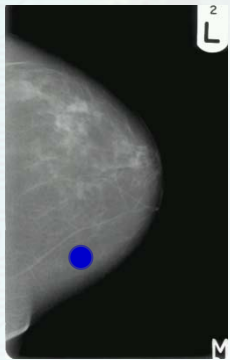
CC



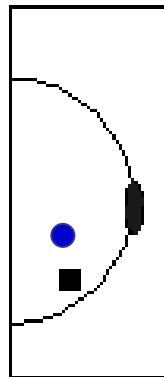
MLO

A CAD system for the 3D location of lesions in mammograms

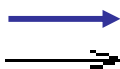
Estimation of 3D location of the lesion detected in both images



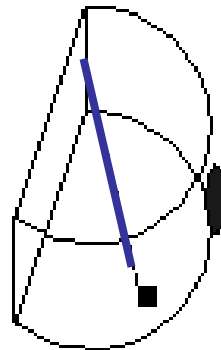
CC



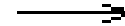
Back
projection



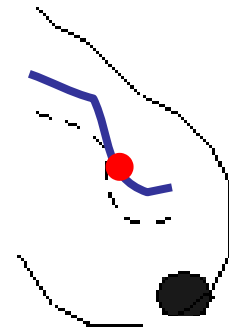
A



Uncom-
pression
model

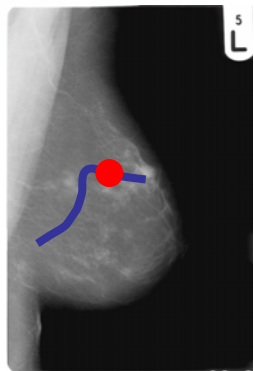


B

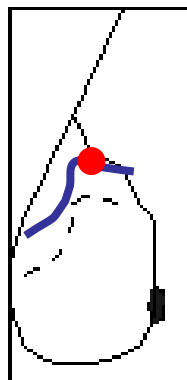


C

Rotation
of X-ray
source

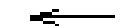


MLO

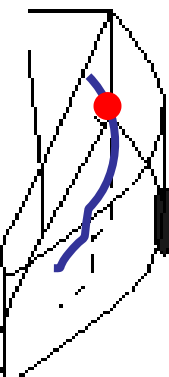


Projection

model



E

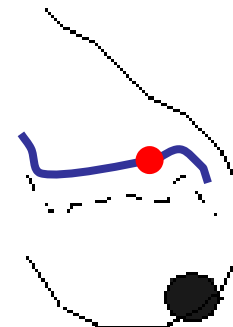


Com-
pression
model

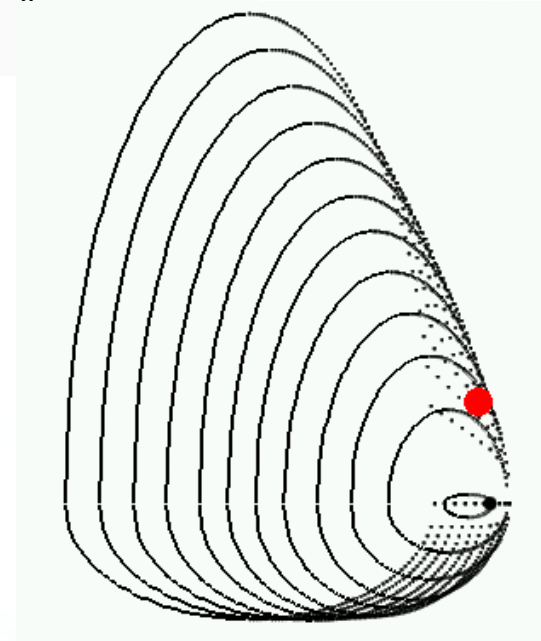
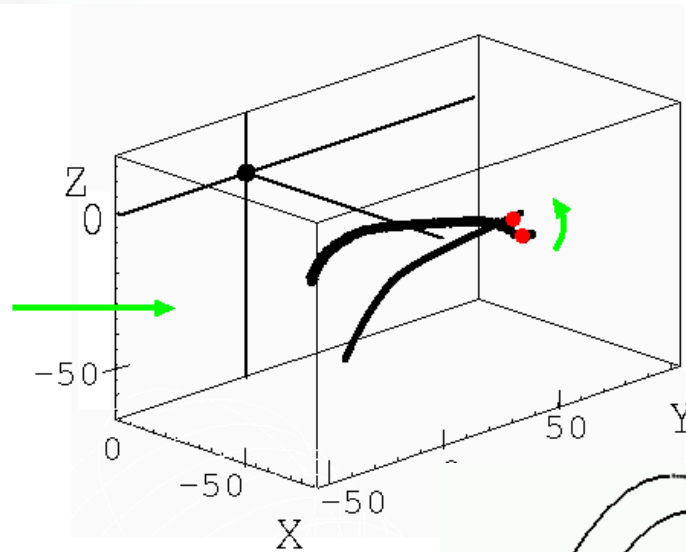
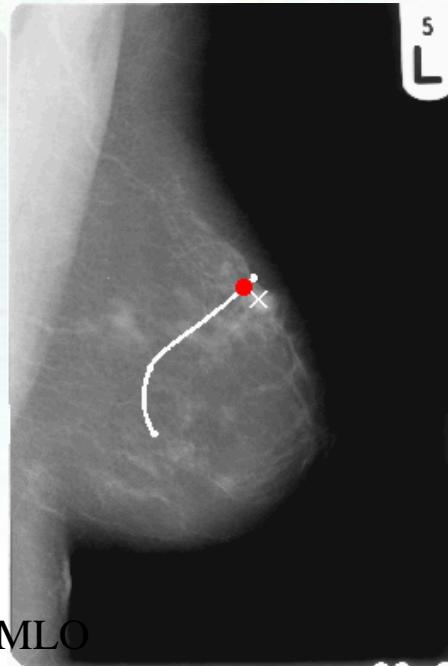
model



D



Example of 3D localization of lesion



Uncompressed breast

Results: prediction of the position in different view

Minimum distance to the correct position(mm)

No	CC->MLO	MLO -> CC
1	8.9	0.2
2	best 0.2	0.3
3	8.1	5.5
4	1.2	0.7
5	wo	
6	17.2	15.0
7	0.3	6.9
8	0.5	1.8
9	0.9	4.5

Less than 2mm 9/18

2mm - 10mm 5/18

10mm - 20mm 4/18

In most of cases, less than 10 mm error

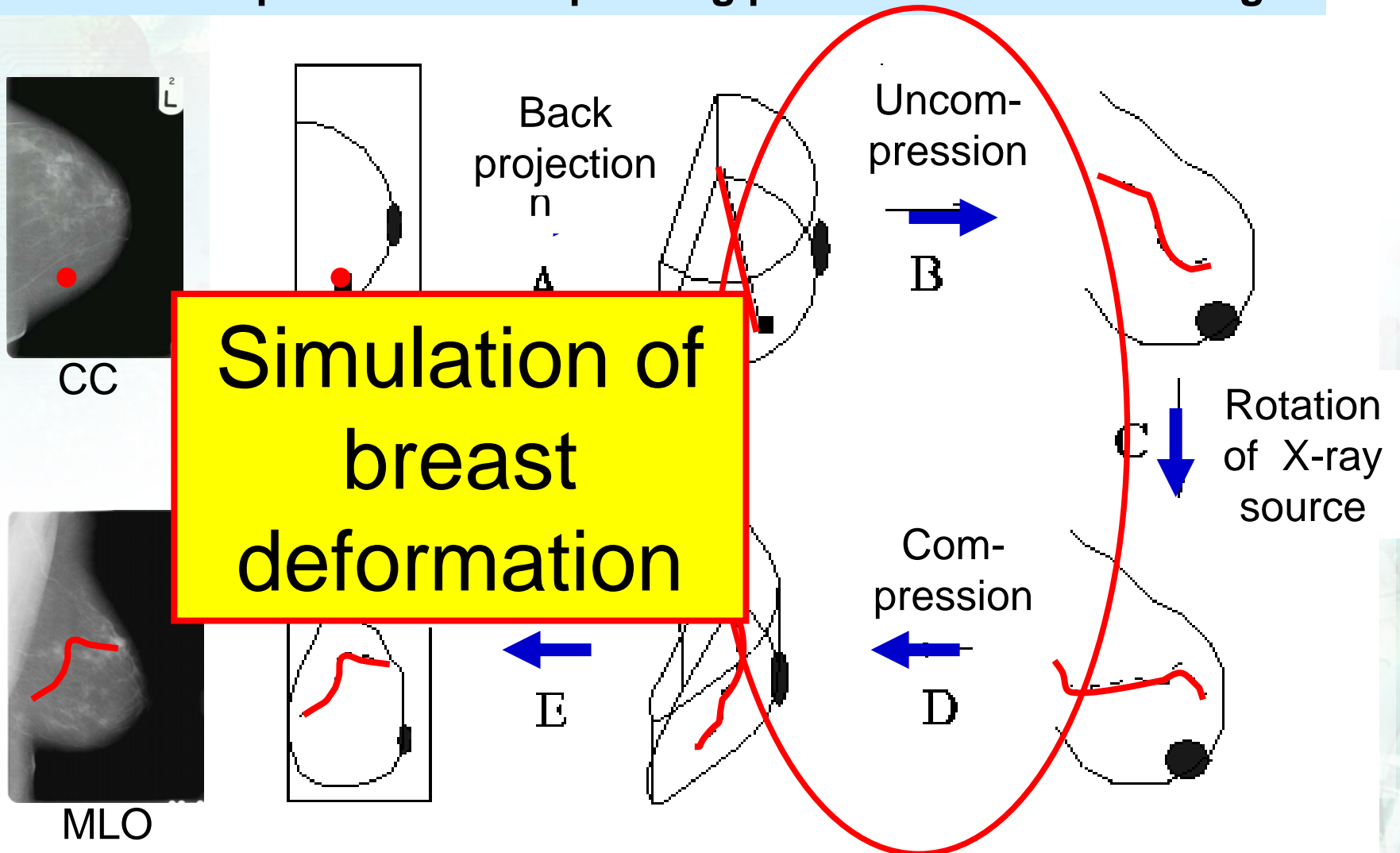
Results: 3D positions

A: Proposed system B: MRI data

No.	Angle at front view(deg)			Ratio in depth			Distance from nipple(mm)		
	A	B	A-B	A	B	A-B	A	B	A-B
1	67	75	8	0.11	0.62	-0.51	39.1	43.0	-3.9
2	-125	-133	8	0.54	0.75	-0.21	43.6	55.7	-12.1
3	142	-176	48	0.41	0.52	-0.11	30.0	33.6	-3.6
4	In most of cases, about 10-20 mm error								
5									
6	119	122	3	0.34	0.69	-0.35	77.6	73.3	4.3
7	62	58	4	0.48	0.72	-0.24	32.8	42.6	-9.8
8	16	6	10	0.37	0.87	-0.50	66.9	57.3	9.6
9	151	178	26	0.39	0.67	-0.15	48.3	37.2	11.1
9	47	43	4	0.25	0.62	-0.27	30.3	36.4	-6.1

A CAD system for the 3D location of lesions in mammograms

Prediction of possible corresponding position in the other image



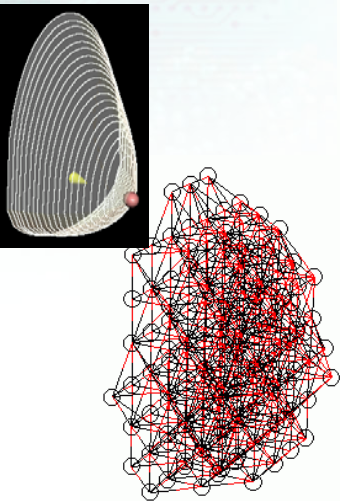


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Simulation of breast compression using a mechanical model

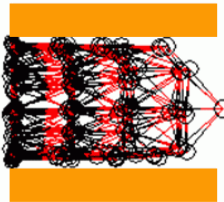
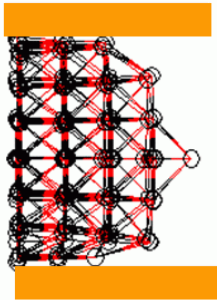
Simulation of breast compression using a mechanical model

MRI MIP data

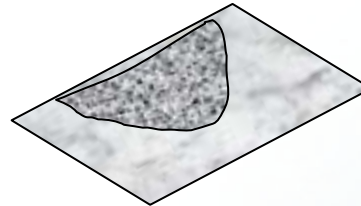


3Dmodel

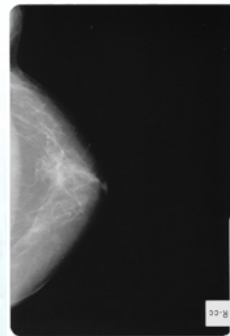
Simulation of
compression



Simulation of
projection

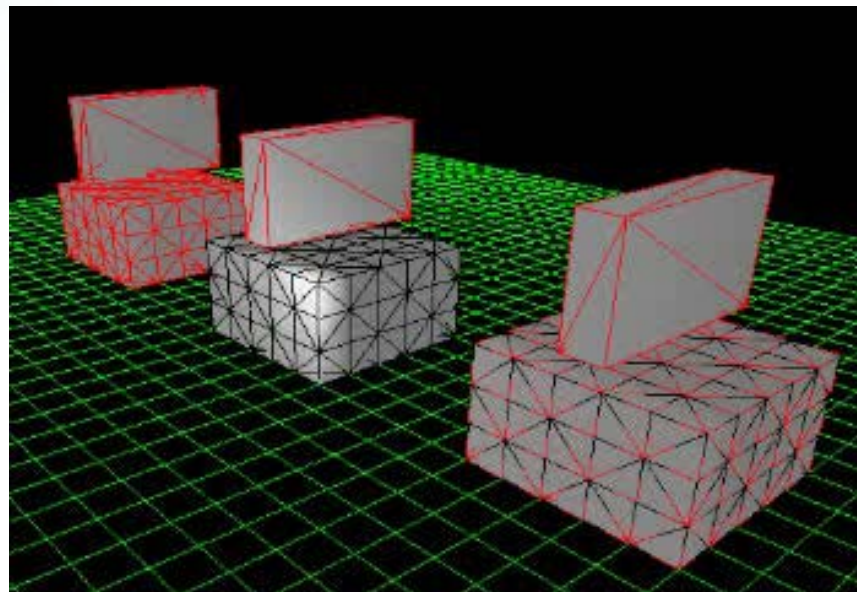
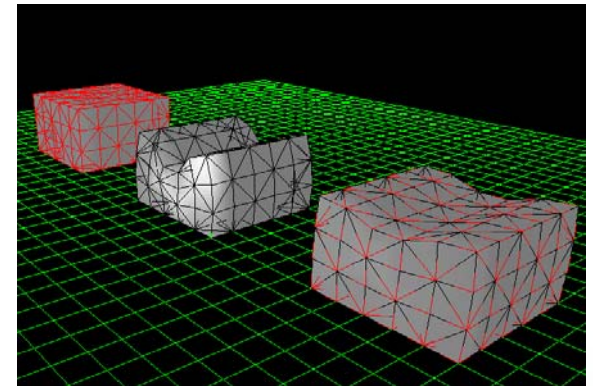
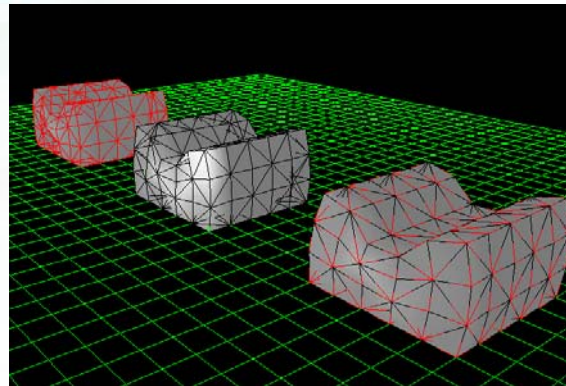
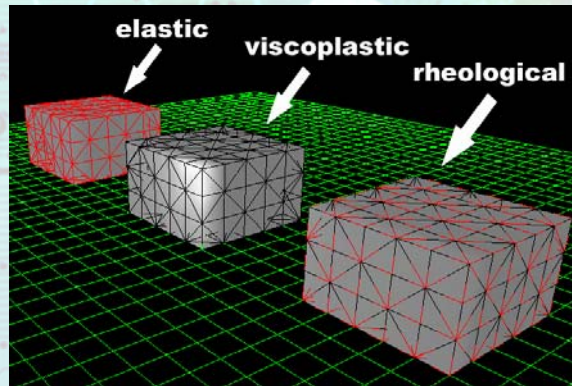


Mammogram



Comparison

Rehological model [Kimura et. al 03]

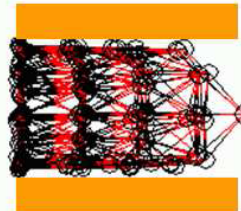
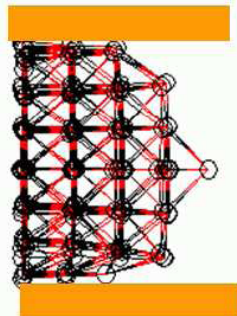
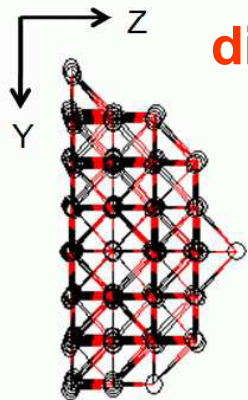


From <http://www.mint.se.ritsumei.ac.jp/images/vro/3dobjs.mpg>

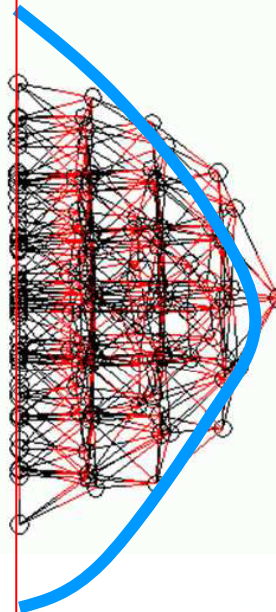
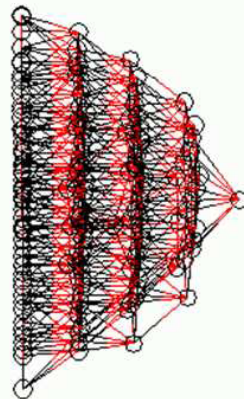
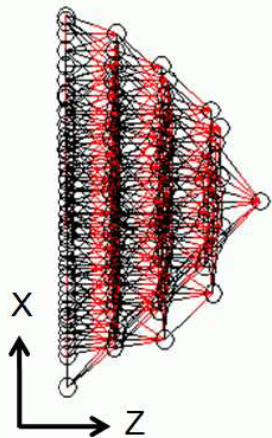
Simulation result1

Compression by plates

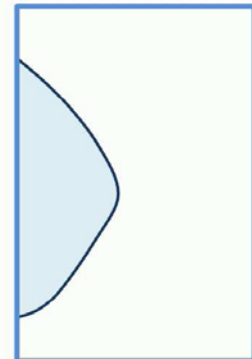
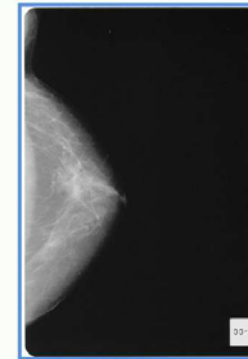
displacement-controlled conditions



Side view



Top view



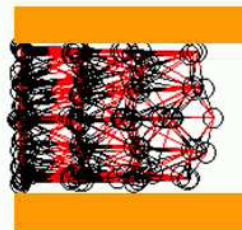
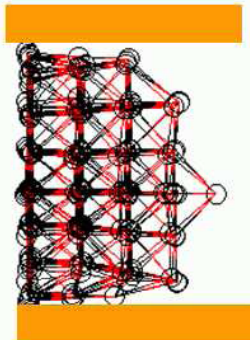
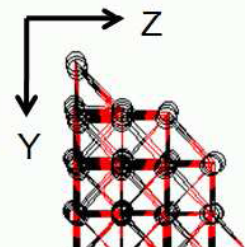
Fixed at chest wall

Z coordinates are fixed

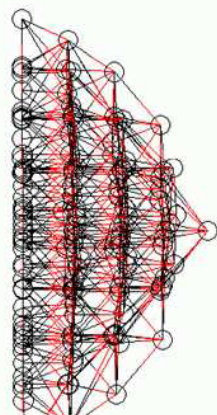
Simulation result 2

Compression by plates

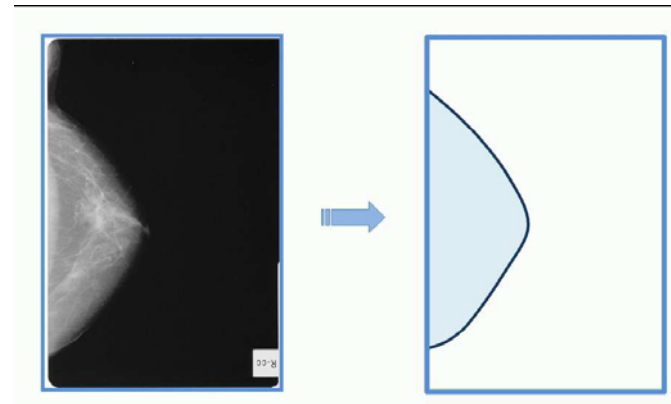
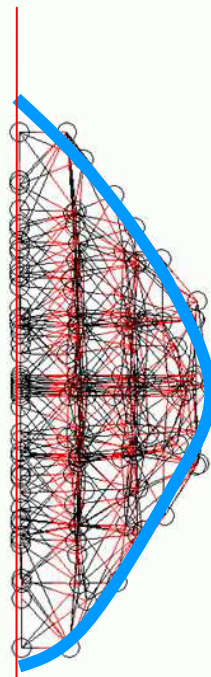
displacement-controlled conditions



Side view



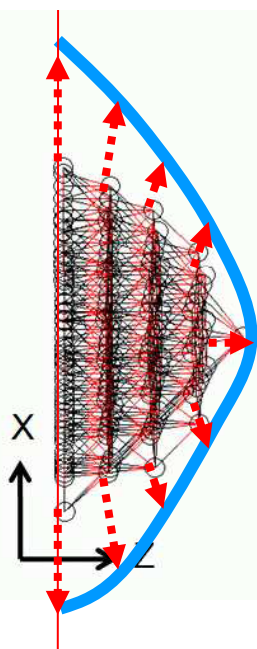
Top view



Fixed at chest wall

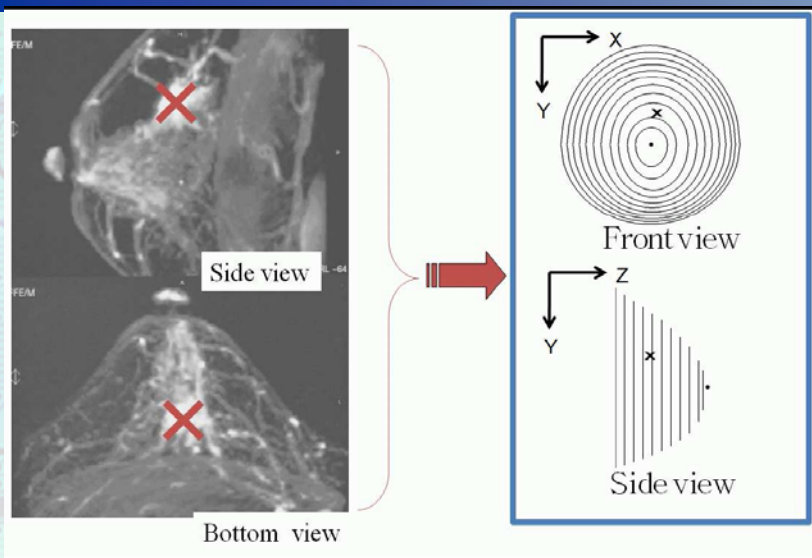
Z coordinates are fixed

+ displacement-controlled conditions



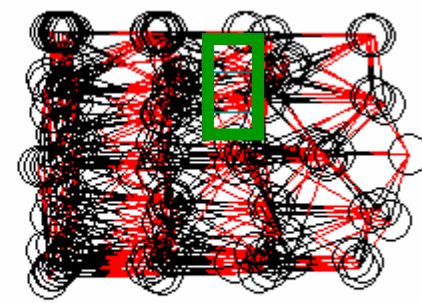
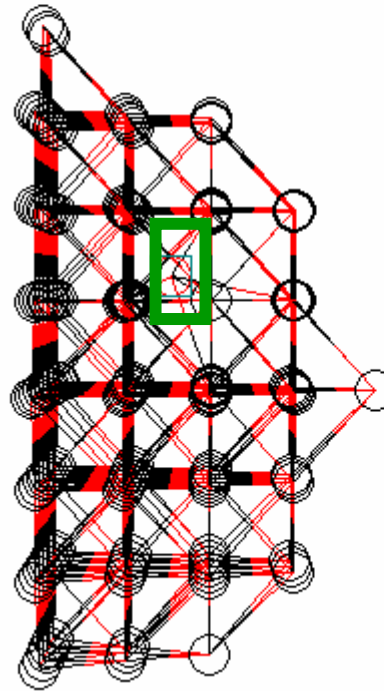


Movement of abnormal lesion^{005r}



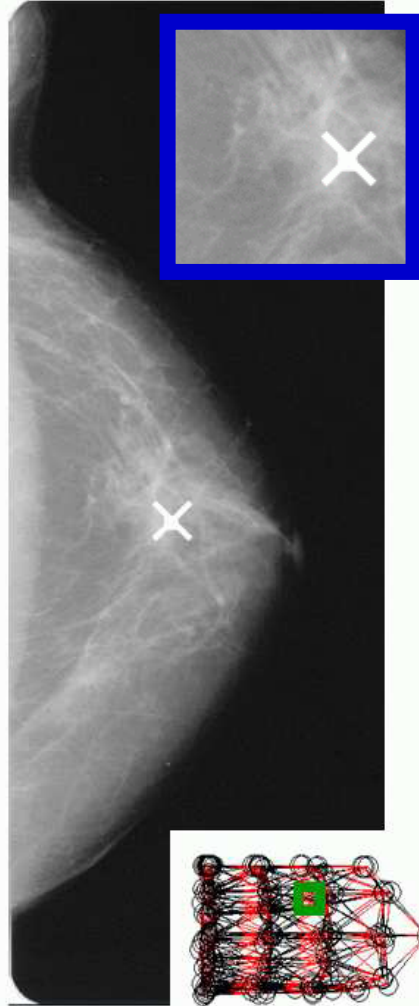
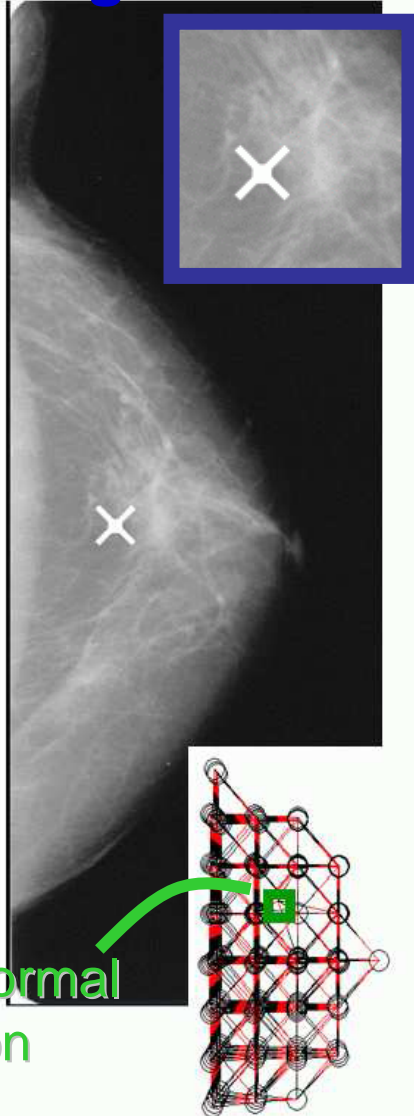
13
.123457
.550000
.381250
700000

time
nodeNo: 113
m : 0.123457
fixed : 0
x : 15.858055
y : 14.990037
z : 7.851313
Vx : 0.024116
Vy : -0.286761
Vz : 0.616996
|V| : 0.6808065



Movement of an internal lesion

Magnification



Abnormal
lesion



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Inspection of internal deformation

Internal deformation measurement

[Tokumoto et. al. 06]

Industrial CT scanner

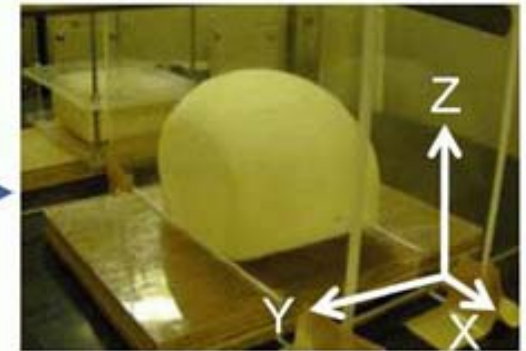
TOSCANER-24200AV

Resolution:

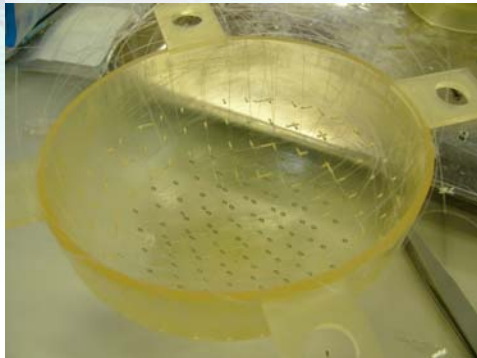
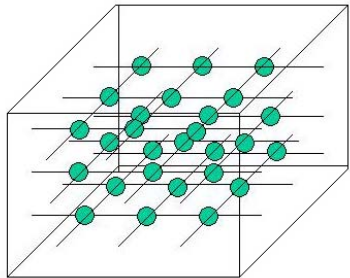
X 0.29mm

Y 0.29mm

Z 0.50mm



Semi-ellipsoid phantom made of human-skin gel



human-skin gel

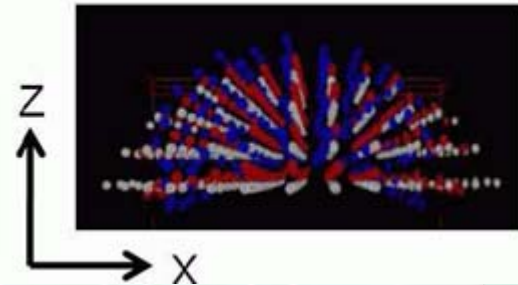
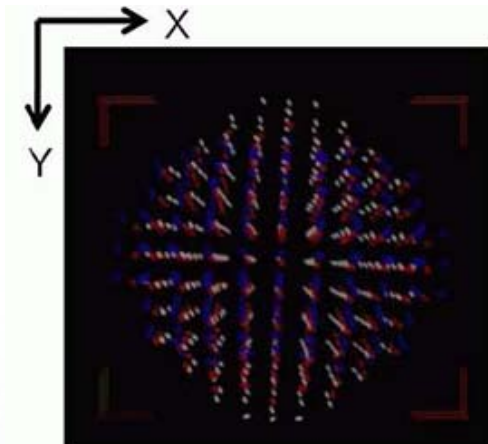
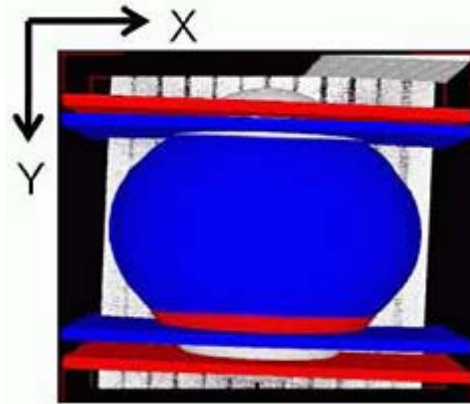
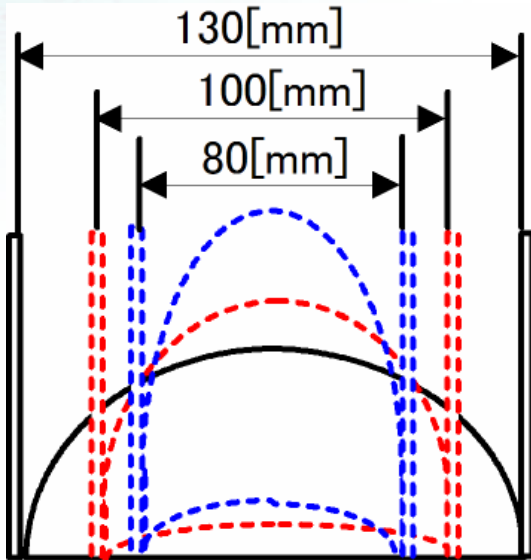
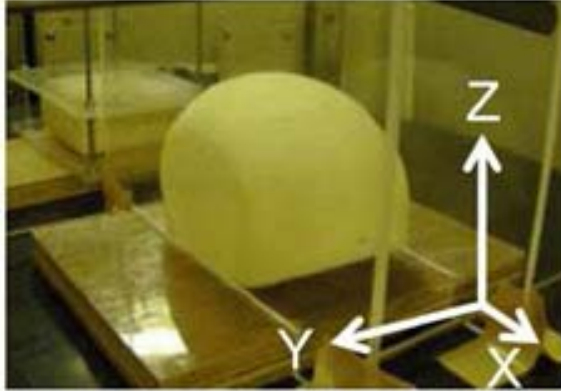
Phantom size:

$130 \times 110 \times 70$ [mm]

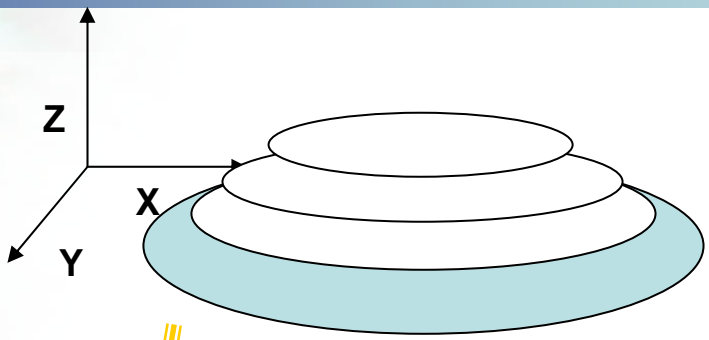
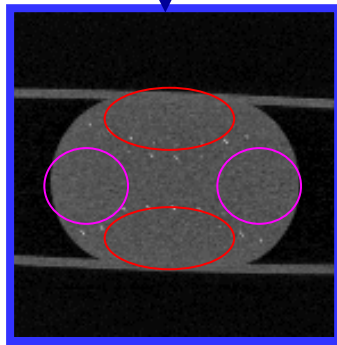
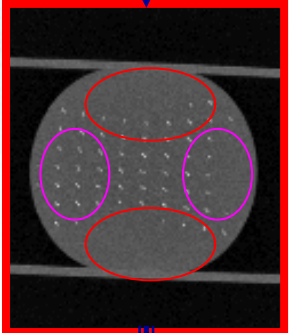
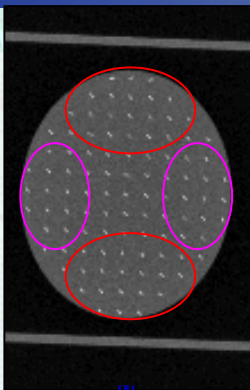
Marker:

286 washers (2.8x2.8x0.3(mm))

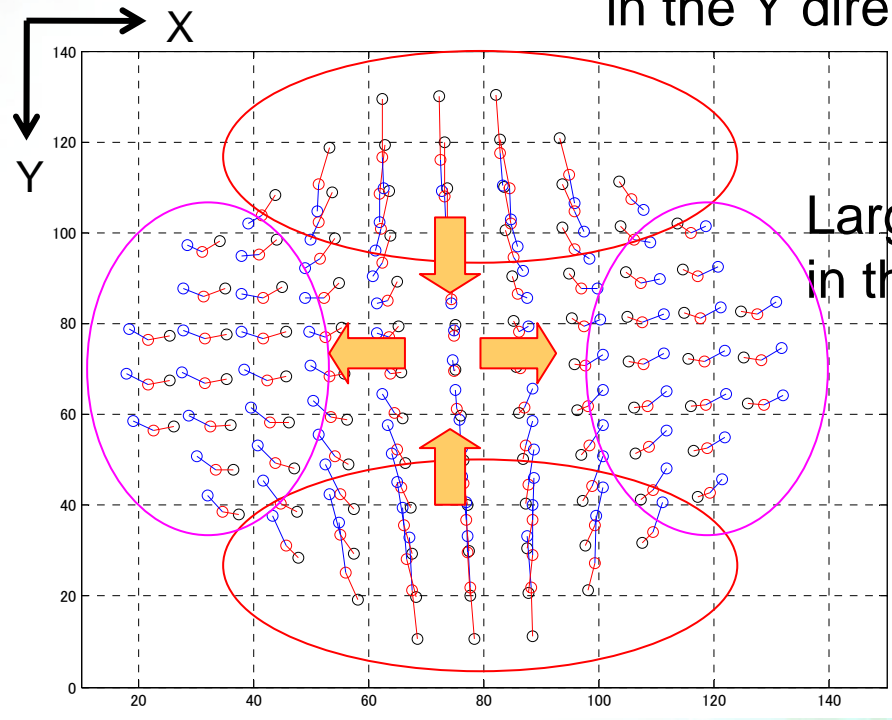
Semi-ellipsoid phantom made of human-skin gel



Observation of internal deformation

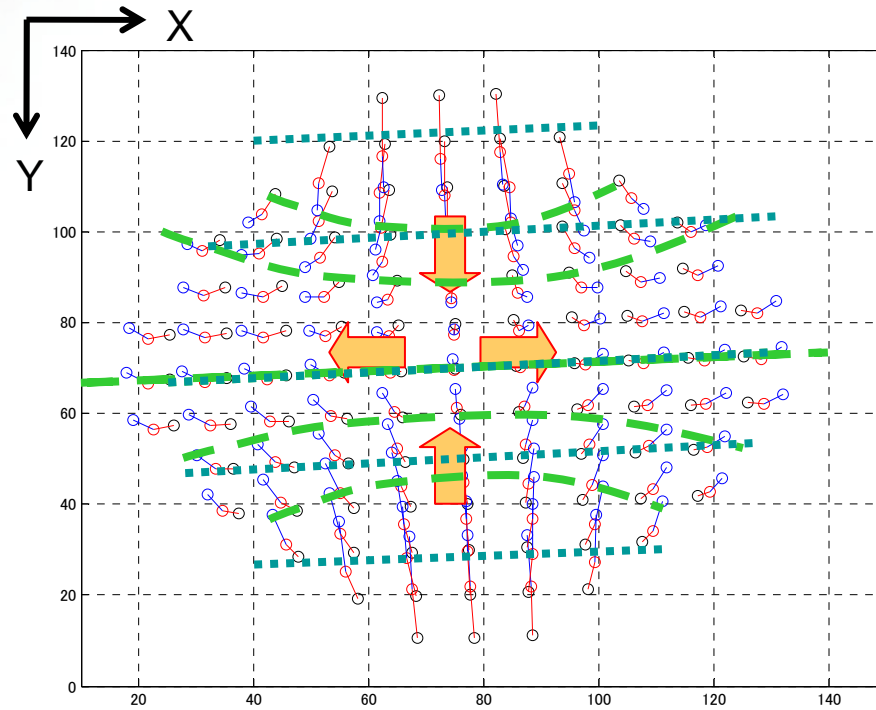
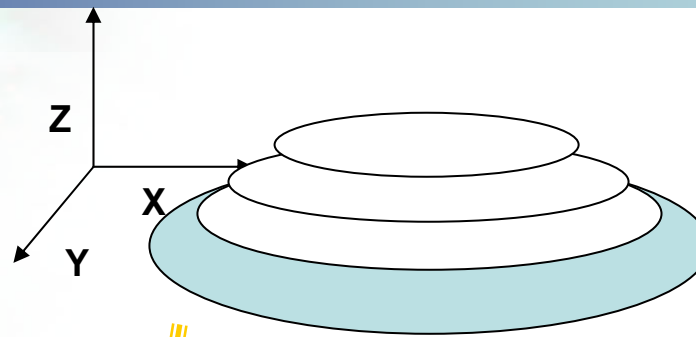
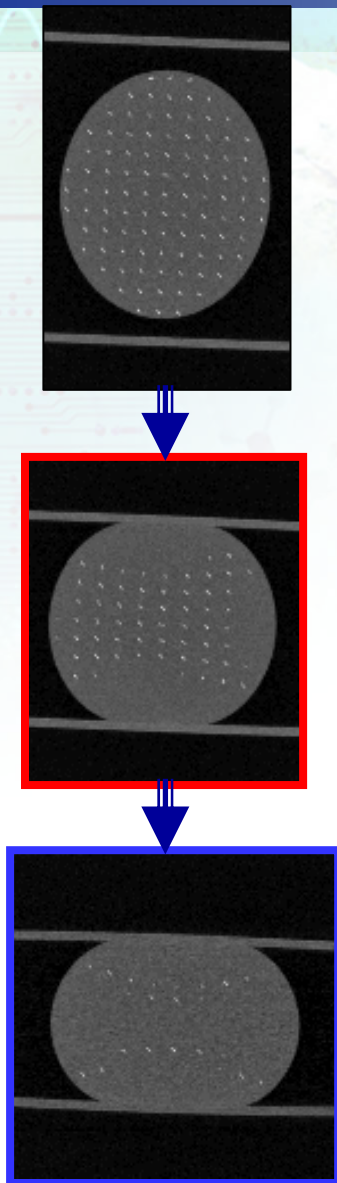


Large displacements
in the Y direction

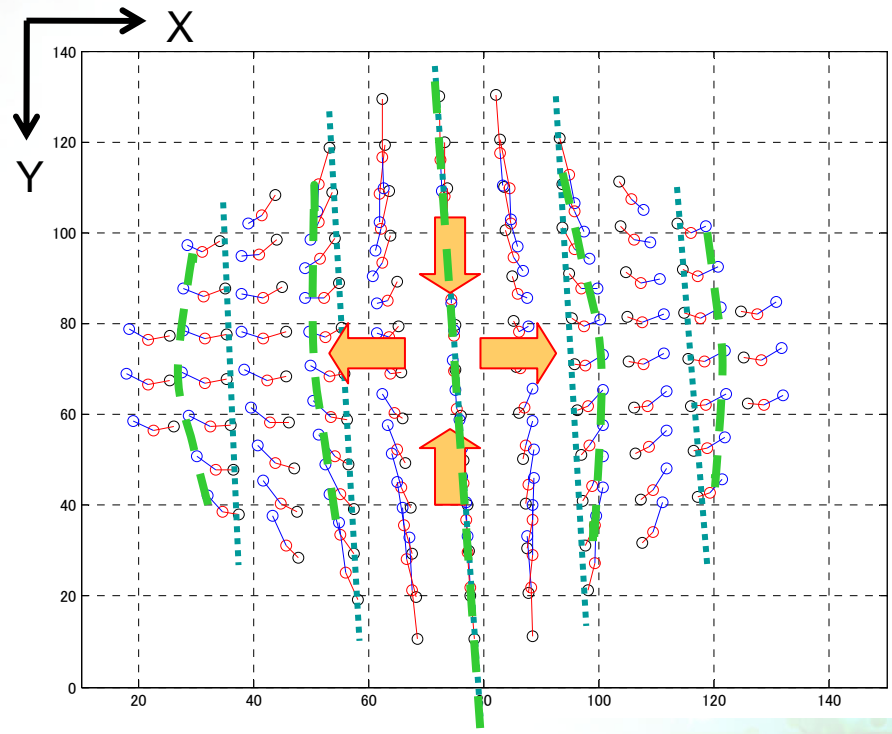
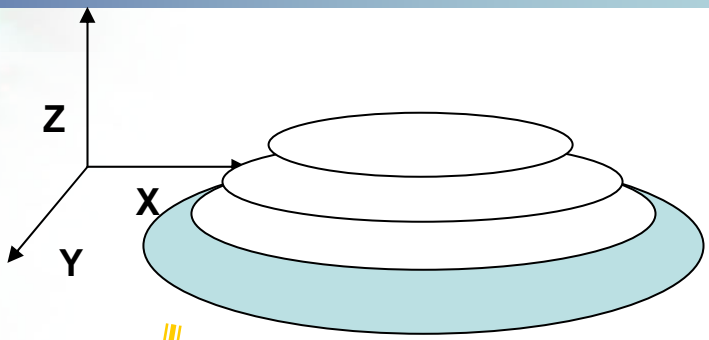
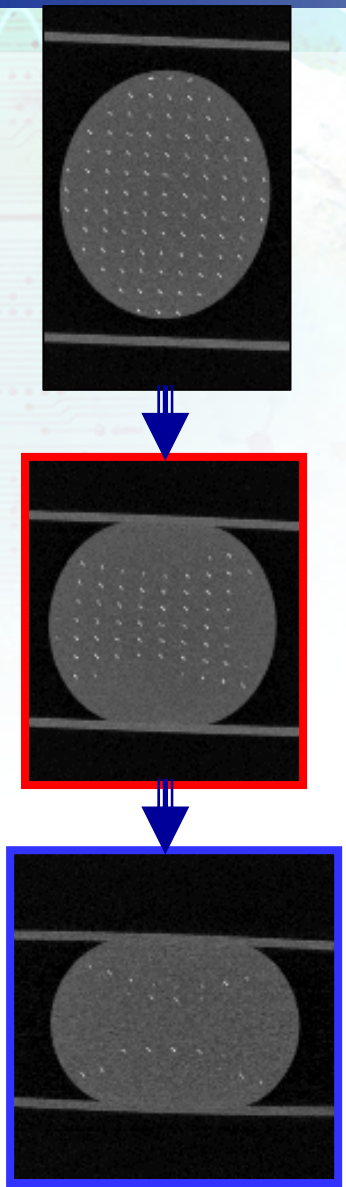


Large displacements
in the X direction

Observation of internal deformation

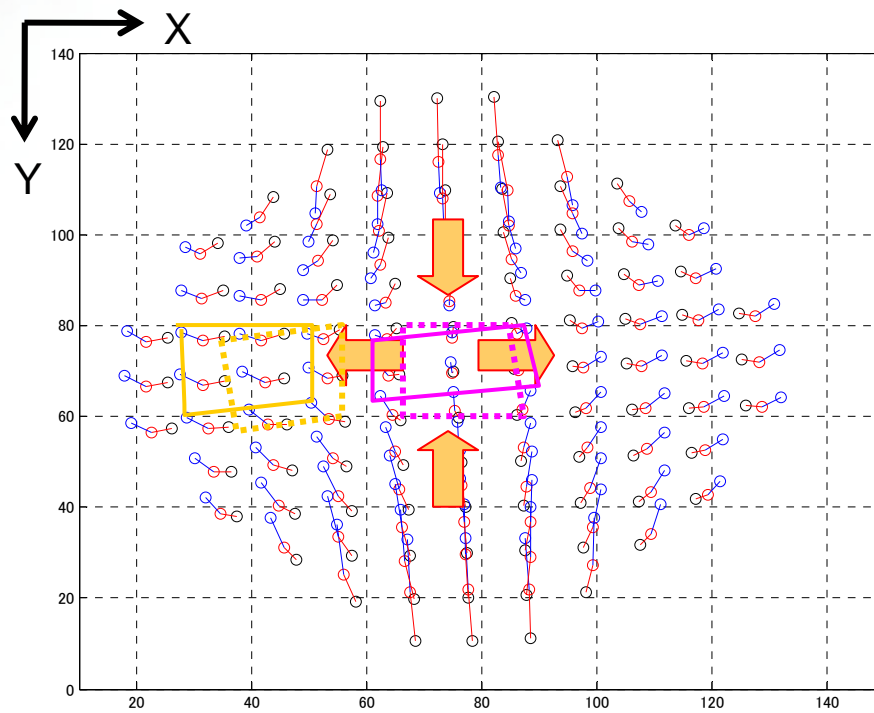
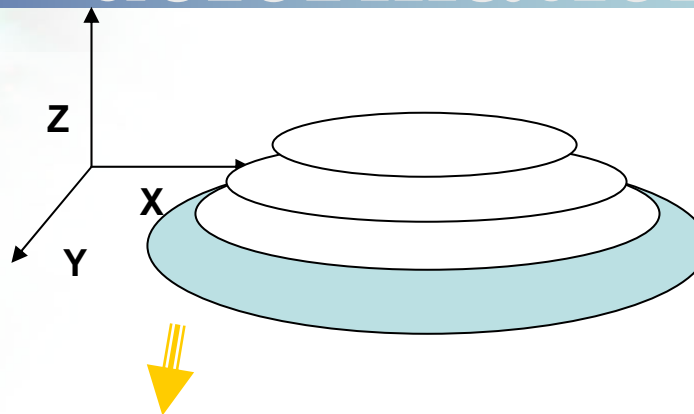
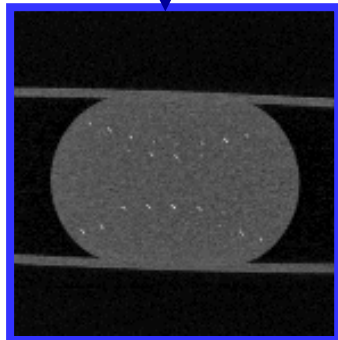
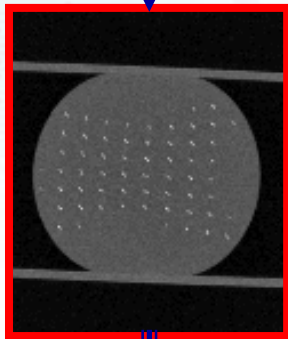
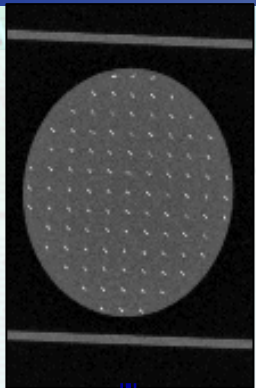


Observation of internal deformation

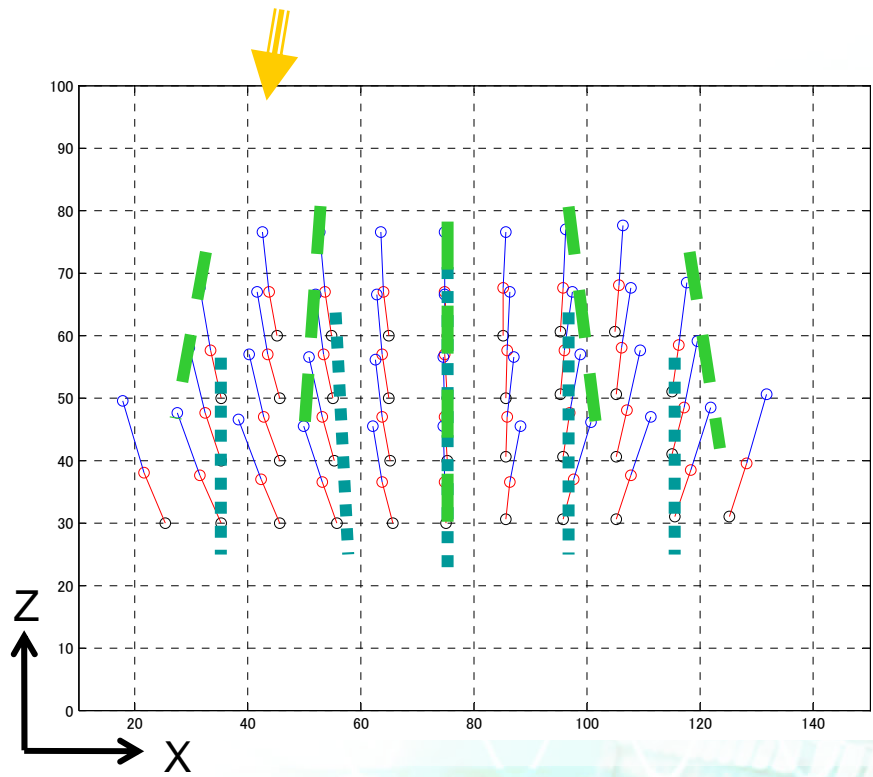
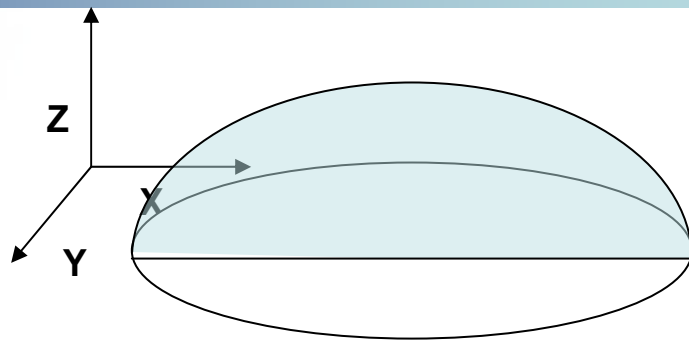
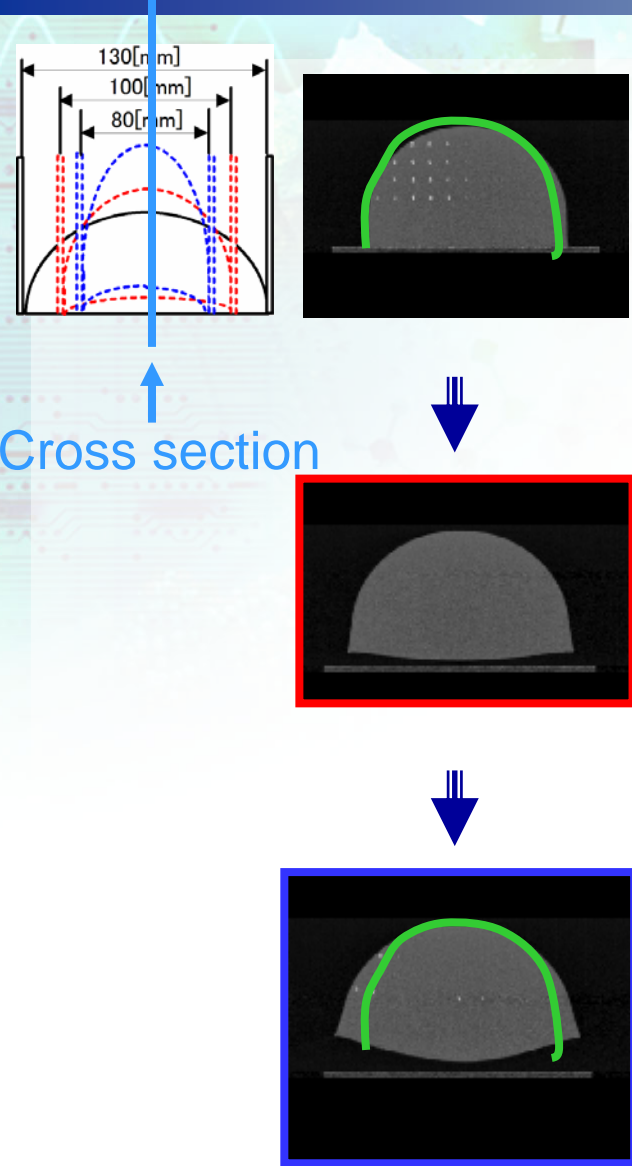




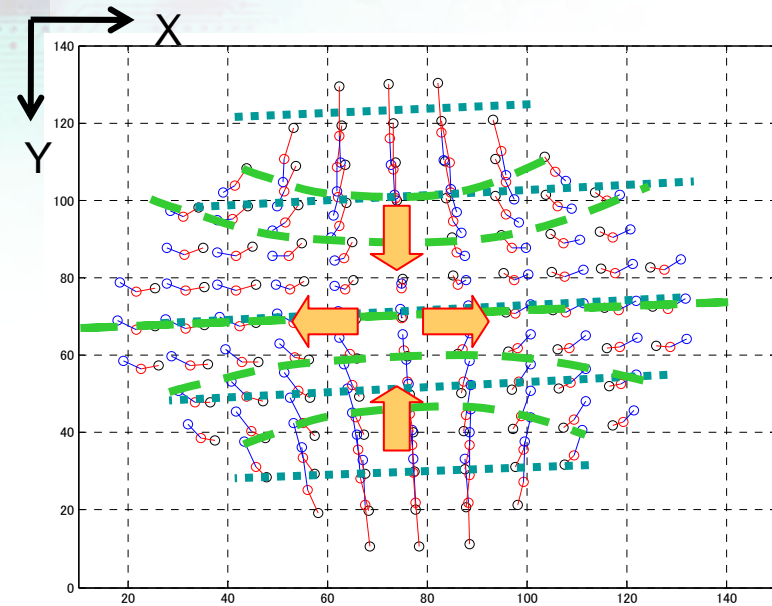
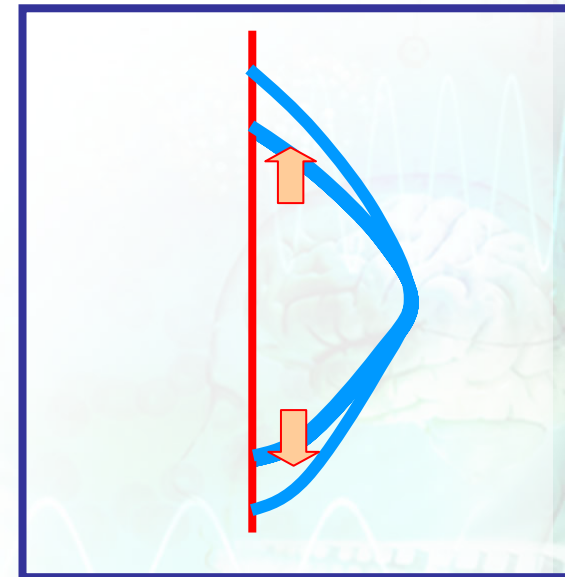
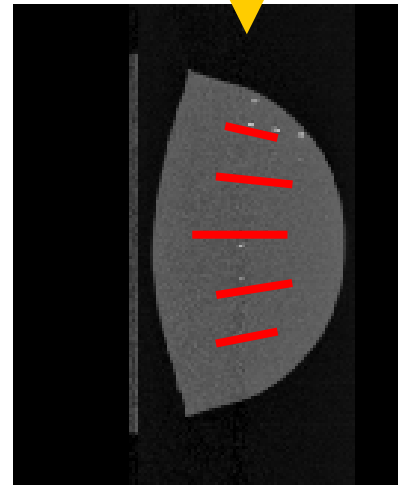
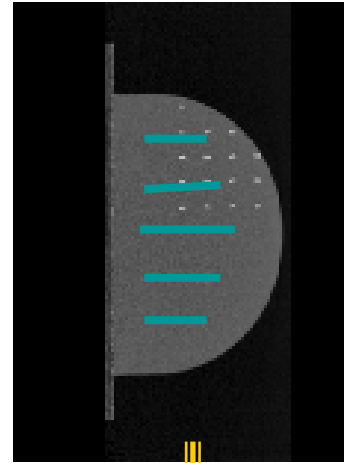
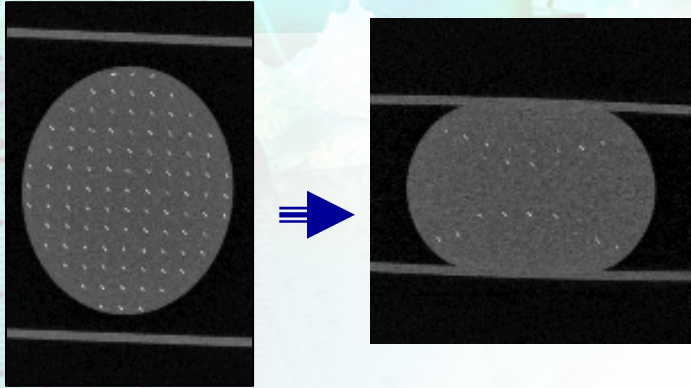
Observation of internal deformation



Observation of internal deformation



Summary of observations

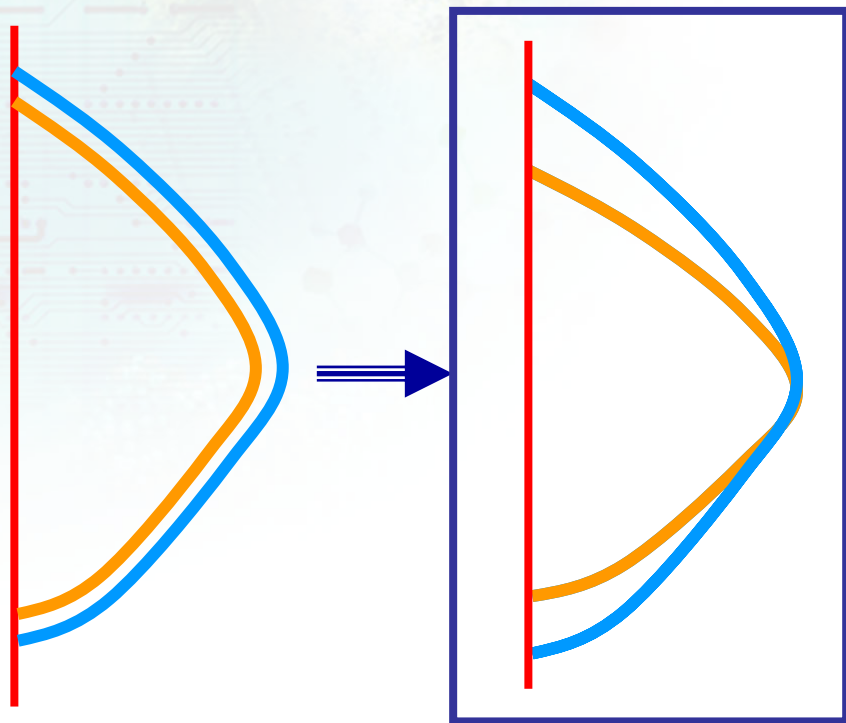


Matters to improve the compression model

Current

From this observations

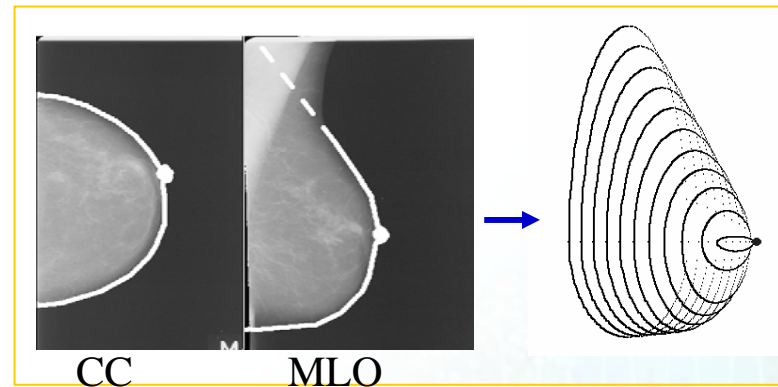
The distortion of the outlines should be considered.



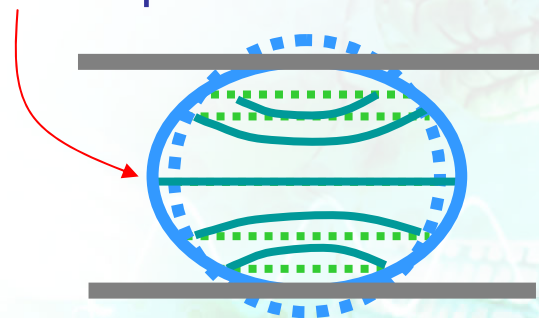
— Outline in Mammogram

— Outline in uncompressed breast

⇒ 1) Reconstruction of 3D shape



⇒ 2) Assumption on the middle plane





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Conclusions

Summary

- Preliminary results on the analysis of breast deformation under strong compression

- 1) Compression simulation using a mechanical model
- 2) Inspection of inside deformation with a phantom

- Key issues to improve the compression model

Breast tends to deform in the direction parallel to the chest wall rather than perpendicular to the chest wall

=> 3D breast reconstruction

=> some approximations used for the compression model.

Future Subjects

- Further investigation of the breast deformation under mammographic compression
- Development of more sophisticated compression model for the CAD system based on the facts obtained from the experiments above.