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Configurable Framework for Automatic Multimodal 2D/3D Registration of Volume Datasets with X-Ray Mammograms

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Motivation

- Correlation of 3D images, e.g. Magnetic Resonance Imaging (MRI) or Ultrasound Computer Tomography (USCT) with X-Ray mammograms (XRM) is challenging due to different dimensionality, patient positioning and deformation state of the breast.
- Image registration may help radiologists in multimodal diagnosis by creating directly comparable images.
- A general parameterizable framework for registration is needed to cover modality specific requirements.

Methodology

- Preprocessing of datasets is done patient-specifically using a toolbox with state-of-the-art methods.
- General concept of registration: mimicking the mammographic compression by Finite Element Method (FEM) simulation.
- The patient-specific biomechanical model is built on basis of preprocessed images.
- Material model and boundary conditions define the deformable behaviour.
- The simulated deformation is applied to the volume image.
- The resulting projection of the volume image has congruently overlaying circumferences with the corresponding XRM.
- Visualization for intuitive presentation of the results can be carried out.
- Processing steps of the registration are parameterizable in order to adapt the registration patient-specifically, e.g.
  - Cut in coronal plane (volume data)
  - Rotation around sagittal axis (volume data)
  - Mesh density
  - Material model

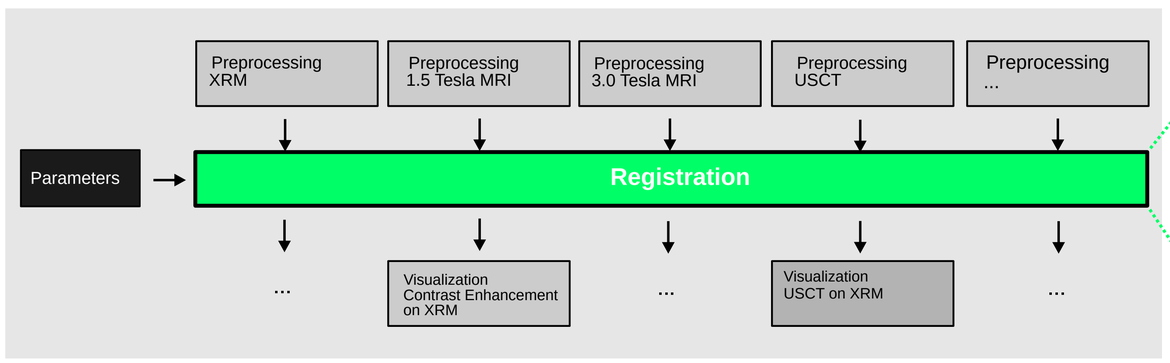

Fig. 1: *Architecture of the breast image registration framework*

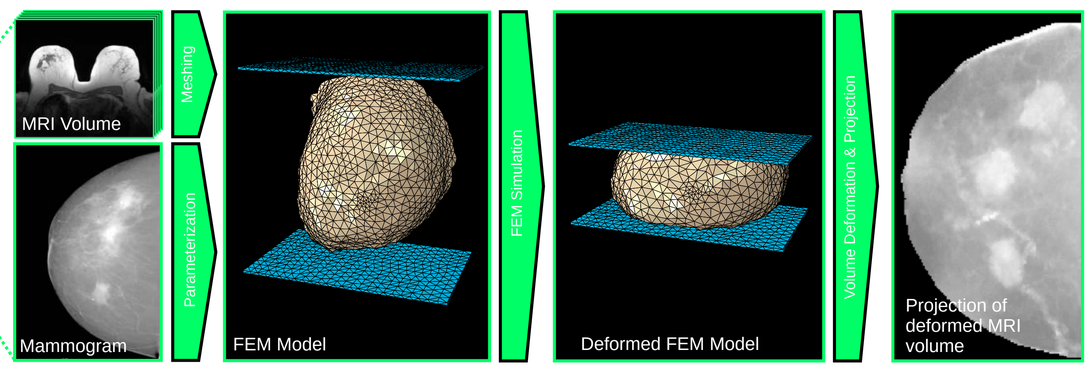

Fig. 2: *Simplified schema of the registration process.*

Results

Registration accuracy is estimated by displacement and overlap of lesion markings visible in both modalities.

Number and origin of clinical datasets	Mean Displacement of lesion markings	Mean Overlap of lesion markings
11 datasets from 1.5 Tesla MRI, University Hospital Jena, GER	11.8 mm ± 6.4 mm	76% ± 34%
7 datasets from 3 Tesla MRI, University Hospital Jena, GER	8.2 mm ± 6.7 mm	79% ± 31%
15 speed of sound datasets from USCT, Karmanos Cancer Institute Detroit, US	12.8 mm ± 12.0 mm (7.1 mm ± 5.4 mm)*	83% ± 27% (91% ± 10%)*

* with manual corrections of dataset rotation due to patient positioning.

Evaluation of the impact of parameters on the registration accuracy using a 1.5 MRI dataset with three spatially distributed lesions.

Parameter	Value range	Mean SD of registration accuracy of three lesions
Coronal plane cut	-35 to +10 pixels from estimated cut	5.6 mm
Sagittal volume rotation	-30° to +30°	3.1 mm
FEM mesh density	1,000 to 100,000 FE	1.3 mm
Fat-gland stiffness ratio	1:0.5 to 1:15	2.4 mm

With more optimal parameters, registration accuracy for the dataset could be improved by approx. 4.6 mm.

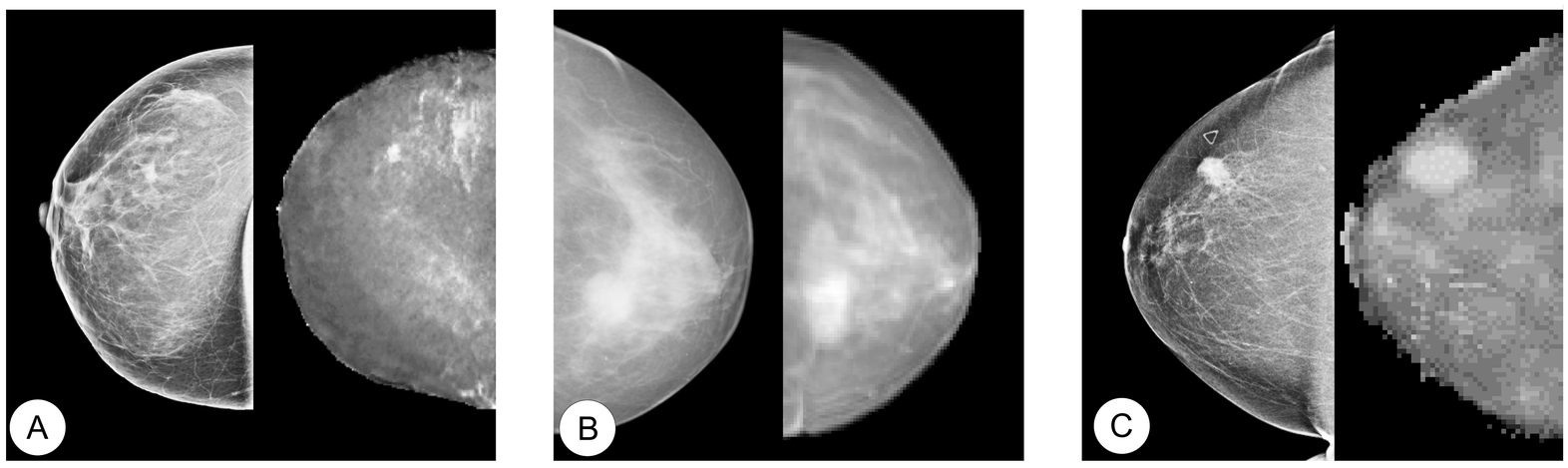

Fig. 3: *Registration results with three different modalities: X-ray mammogram (left) and projection image of the registered volume image (right) acquired by (A) 1.5T MRI, (B) 3T MRI, (C) USCT.*

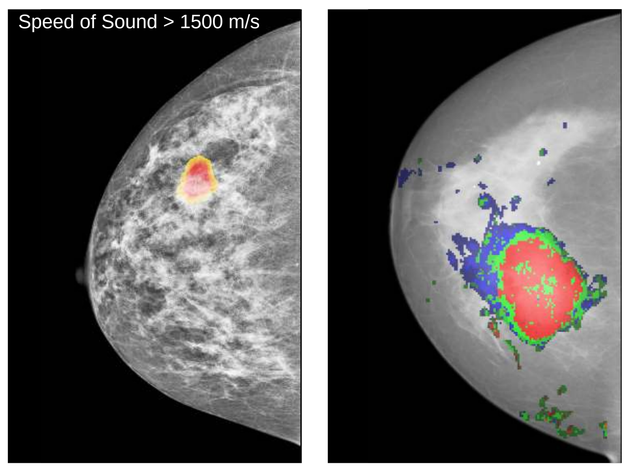

Fig. 4: *Examples for intuitive visualization of registration results: XRM overlaid with USCT information (left) and XRM overlaid with contrast enhancement information from MRI.*

Conclusion

- Parameterizable framework allows to automatically register 3D images patient-specifically with the corresponding XRM.
- Diagnosis benefits from the spatial correlation as well as from the combination of two complementing modalities.
- Evaluation with 1.5T MRI, 3T MRI and USCT showed promising results with a registraction accuracy better than 15 mm using empirically chosen parameters.
- Patient-specific parameters improve the registration accuracy.
- Next step will be the automatic estimation of optimal parameters using image similarity measures.