Relating findings between breast MR images and X-ray mammograms: A validation study on clinical cases

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X-ray mammography and Magnetic Resonance Imaging (MRI) are commonly used to investigate symptomatic patients and women with dense breasts. Relating findings between breast images from different modalities is a challenging task, due to the highly deformable nature of the breast and the differences in image appearance. Therefore, a methodology for the automated alignment of the two images could be valuable for radiologists. To determine the accuracy of an intensity-based registration algorithm between the two modalities and to investigate its applicability in clinical practice, we present in this work the results of a validation study performed on clinical images of 49 subjects. The median registration error calculated on 113 registration tasks was $13.1mm$. This indicates that an intensity-based registration algorithm, using a relatively simple transformation model, can provide radiologists with a clinically useful tool for breast cancer diagnosis.

1 Background

X-ray mammography is routinely used both as a screening and as a diagnostic tool for the early detection and management of breast cancer. Although the resolution of an X-ray mammogram is high, enabling the detection of small findings, such as microcalcifications, the superimposition of normal fibro-glandular structures can cause ambiguities, especially in women with dense breasts. Dynamic Contrast-Enhanced MRI is commonly used as a complementary modality, as it provides functional information and a 3D image of the breast. This enables the detection of lesions that are not visible in X-ray mammograms or further evaluation of mammographically detected findings. Establishing corresponding regions between the two modalities is a difficult task for the radiologists, due to the imaging processes involved and the large deformation of the breast during image acquisition.

Previously, authors have used feature-based techniques ([1], [2]) or patient-specific models [3] for this task. Both approaches cannot be easily integrated in clinical practice and often require manual interaction. We propose the use of an intensity-based approach for registration [4], where the images are aligned according to the matching of the internal breast structures in addition to the outline, rather than the breast outline only or image-extracted features.

2 MRI to X-ray registration framework

The overview of the registration framework is illustrated in Figure 1. Before registration the MR intensities are mapped to X-ray attenuation via a breast-tissue classification algorithm, that classifies the voxels as either fibro-glandular or adipose tissue. The new X-ray attenuation volume and the X-ray mammogram are the inputs to the registration framework. To approximate the mammographic compression, we use a volume-preserving affine transformation. The parameters of this transformation (translations, rotations, scaling and shear) are iteratively updated.

During registration, a simulated mammogram is generated from the attenuation volume, at the current transformation parameters, by a ray casting algorithm. The similarity (normalised cross-correlation) is then calculated between the real and the simulated mammogram and based on the value of this metric the

3D affine transformation parameters are updated. The process is repeated until convergence. The final transformation parameters can be used to map any coordinate in the MRI to the corresponding location on the Cranio-Caudal (CC) or Medio-Lateral Oblique (MLO) view mammogram.

3 Experiments

For validation we have performed a total of 113 registration tasks, which include both CC (n = 55) and MLO (n = 58) view mammograms. The number of patients used was 49. All images included findings clearly visible in both modalities that were annotated. We have also included one case with an MRI and X-ray compatible clip at the lesion's position that was used as a ground truth corresponding point.

We used as an error metric the 2D Euclidean distance between the centres of mass of the X-ray annotation/clip and the projection of the MR annotation/clip, after being deformed with an affine transformation and projected. The total histogram of the registration errors and an example case are given in Figure 2. The median registration error was $13.1mm$. The distributions of the registration errors for the CC and MLO view mammograms separately are similar (median $12.9mm$ for the CC and $13.5mm$ for the MLO view). The mean accuracy for both views of the patient with the clip was $8.9mm$.

4 Conclusions

We have validated an intensity-based registration framework for the mapping between MRI and X-ray breast images, using a volume-preserving affine transformation. Our methods aims to approximate the highly non-linear deformations of a real breast deformation, whilst being fast to compute and straight forward to translate into a clinical context. The results indicate that this technique can provide radiologists with a clinically useful tool for breast cancer diagnosis.

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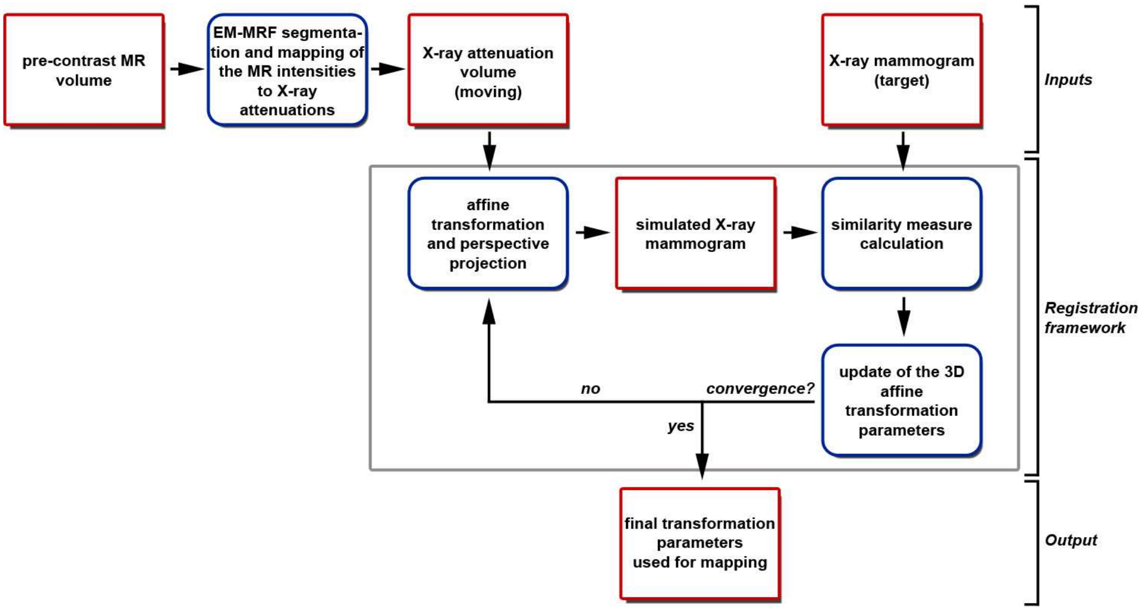
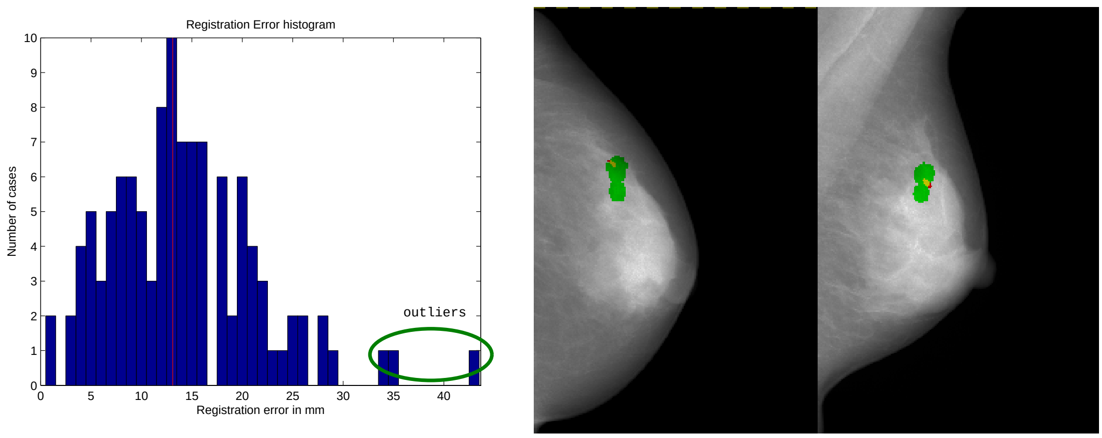


Figure 1: Overview of the MRI to X-ray registration framework. The processes are illustrated in blue and the data in red.



(a) (b)

Figure 2: (a) Histogram of the registration errors calculated from 113 registration tasks using corresponding lesions, manually annotated by experienced observers in both the MRI and X-ray images. In red is shown the median value ($13.1mm$) and in green the outliers. (b) An example case, where the X-ray annotation is illustrated in red and the projection of the MRI annotation in green. Their overlap is yellow. The error for the CC view is $6.8mm$ and for the MLO view $2.6mm$.