

# Generation of digital breast phantoms and synthetic mammograms

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**Abstract**—The aim is the generation of synthetic mammograms, starting from the reconstruction of breast digital phantoms from computed tomography (CT) images, exploiting trivariate tensor product B-splines. The phantoms are modified by means of geometrical transformations that replicate typical breast shape deformities, and by introducing artificial lesions. After biomechanic compression, we simulate the x-ray - phantom interaction, to generate realistic mammograms.

**Clinical Relevance**— This enables us to obtain a range of mammograms with large variability in terms of shape, and type and location of lesions, providing a tool for the creation of an extended synthetic database for AI training and benchmarking.

## I. INTRODUCTION

Anthropomorphic phantoms can be a valuable tool for *in silico* testing and optimization of diagnostic techniques. They can be used for the generation of synthetic images by means of physical computational modelling, with the scope of expanding existing medical image datasets [1]. This can allow the creation of large databases, to be employed for the robust training and accurate validation of AI models. Here, we focus on the reconstruction and transformation of breast digital phantoms from CT images, providing a tool for the generation of a variety of synthetic mammograms with an *in silico* approach that leverages VICTRE pipeline [2].

## II. METHODS

Breast CT slices with a spatial resolution of 273  $\mu\text{m}$  are used as an input for the generation of the digital phantoms [3]. Tissue segmentation is performed on the entire breast volume, obtained by combining the CT slices on the coronal view from muscle to nipple direction. The discretization, in cubic voxels of 109  $\mu\text{m}$  size, and the identification of the main tissues (fibroglandular, adipose and skin) is aided by trivariate tensor product B-splines, which enable us to determine the gray-level thresholds for semi-automatic tissue segmentation. Geometric transformations are then applied to the obtained phantoms, replicating realistic deformities of breast shape. Additional modifications include the artificial insertion of lesions, like circumscribed and spiculated masses, and calcifications.

Finally, to generate the synthetic mammograms, we first compress the phantoms by means of the finite element biomechanics solver FEBio [4]. The compressed phantoms

are then used as an input to the Monte Carlo x-ray solver integrated in VICTRE, which enables us to obtain “for presentation” images [2].

## III. RESULTS

As an example, Fig.1 shows a set of breast phantoms and synthetic mammograms that can be obtained with the implemented methodology.

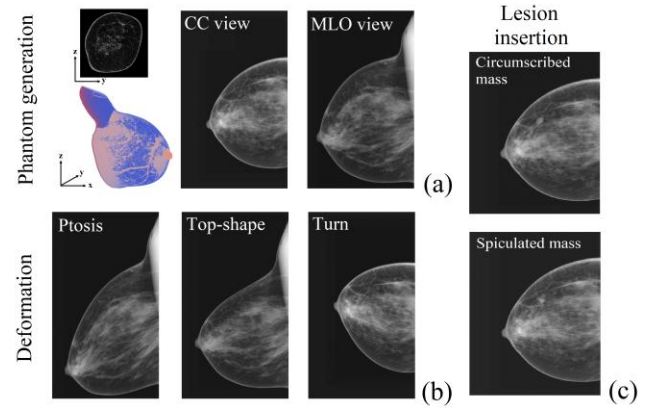


Figure 1. (a) Breast phantom derived from CT slices and associated mammograms in CC and MLO views; (b) mammograms obtained after phantom deformation; (c) mammograms with artificial lesions.

## IV. DISCUSSION & CONCLUSION

The methodology here proposed can contribute to the creation of synthetic mammogram databases, to be used for *in silico* testing of diagnostic and therapeutic techniques, as well as for the validation of AI models in diagnostic imaging. The great advantage is that, from a single set of CT images, it is possible to generate a large number of realistic mammograms, with different anatomical features.

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