Implicit neural networks for breast ultrasound image segmentation

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Abstract
Breast cancer is the most common cancer in women, and ultrasound (US) imaging is important for breast mass assessment. Accurate automatic breast mass segmentation facilitates mass characterization. Traditional deep learning methods, such as convolutional networks and transformers, have achieved high performance in breast mass segmentation. Recently, implicit neural representations, which use continuous, nonlinear, coordinate-based approximations through multi-layer perceptrons, have shown promise in various fields, including medical image segmentation. In this work, we present an implicit network for breast mass segmentation in US. We train a coordinate-based implicit network to jointly output the US image pixel values and the segmentation pixel scores. The network is conditioned using latent codes, effectively associating the regression and segmentation tasks with the mass type (benign/malignant) and BI-RADS category. Additionally, a trainable image-specific code is used. During inference, given a US image, we fix the weights of the network and use the backpropagation algorithm to determine the latent codes, facilitating the image regression task. This process, due to

the learned associations, also provides the segmentation mask. Our results confirm the feasibility of using implicit networks for breast mass segmentation and other tasks leveraging learned associations between latent codes and image/mask appearances.

Introduction

Breast cancer is the most common cancer in women, and ultrasound (US) imaging is widely used for breast mass assessment. Accurate automatic breast mass segmentation facilitates mass characterization, as malignant lesions often have more variable shapes compared to benign lesions. Over recent years, various deep learning methods, primarily based on feed-forward convolutional networks or transformers, have been proposed for this task, achieving excellent performance with high agreement with manual annotations by medical experts.

Recently, implicit neural representations (INRs) have gained attention in computer vision and computational physics. INRs provide a continuous, nonlinear, coordinate-based approximation of target quantities using a multi-layer perceptron. In computer graphics, INRs are used to efficiently handle high-resolution data and are well-suited for tasks like differentiable rendering and scene reconstruction due to their ability to interpolate and generalize from sparse data. Singh et al. demonstrated that a single polynomial implicit network could represent large datasets like ImageNet, enabling tasks such as guided image generation or style-mixing. [1].

Implicit networks have emerged as a novel approach for medical image segmentation, offering several advantages over convolutional networks or transformers. Stolt-Anso et al. used implicit networks for cardiac segmentation in MRI. Authors trained a multi-task coordinate-based implicit network to jointly output MRI image pixel intensity values and segmentation mask scores [2]. This network was conditioned with an image-dependent latent code, efficiently relating the tasks of joint image regression and segmentation mask computation.

Methods

In this work, we extend the approach by Stolt-Anso et al. and develop an implicit network for breast mass segmentation in US. To our knowledge, this is the first application of implicit networks for this purpose. Our framework is presented in Fig. 1. Compared to the original approach, our method includes several innovations. In addition to a trainable latent code sampled from a normal distribution, we condition the network using latent codes related to BI-RADS category and breast mass type (malignant/benign), which allows the network to associate US image regression and mass segmentation tasks

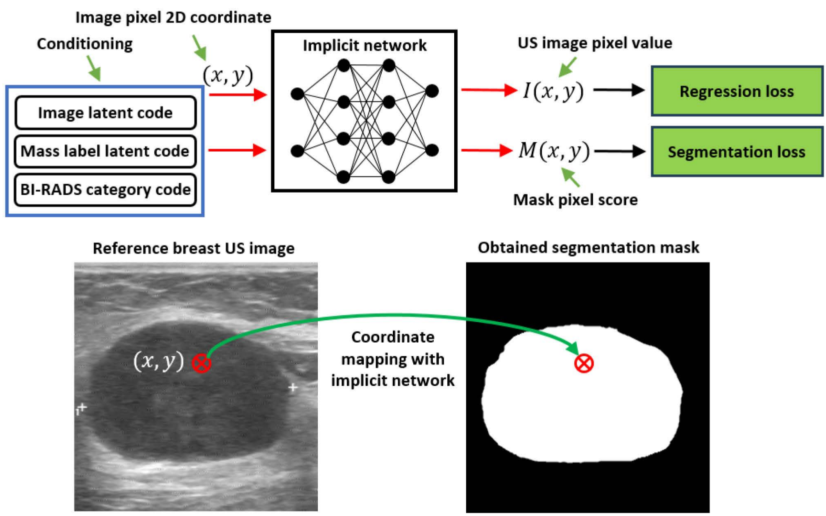

FIGURE 1
We train a coordinate-based implicit network to jointly output the US image pixel values and the segmentation pixel scores. The network is conditioned using latent codes, effectively associating the regression and segmentation tasks with the mass type (benign/malignant) and BI-RADS category. Additionally, a trainable image-specific code is used. During inference, given a US image, we fix the weights of the network and use the backpropagation algorithm to determine the latent codes, facilitating the image regression task. This process, due to the learned associations, also provides the segmentation mask.

with clinical descriptors of the pathology. This conditioning mechanism opens new possibilities. For example, the network may learn to associate the complex shape of a breast mass with malignancy. During inference, we freeze the network weights and use the backpropagation algorithm to regress the test US image and determine the latent code along with the segmentation mask. Furthermore, the learned associations between US images, segmentation masks, and clinical descriptors can be leveraged for several tasks. For instance, we can determine the latent codes corresponding to the BI-RADS category and classification label, effectively transforming the implicit network into a classification model. Additionally, given a segmentation mask and a latent code, our method can address tasks related to image inpainting or interpolation.

Experiments and Discussion

We trained our network using the BUS-BRA dataset, which includes around 1800 breast US images with BI-RADS categories and malignant/benign labels [3]. Our approach was also evaluated using the UDIAT dataset [4]. The segmentation branch was trained using a Dice score-based loss function, while mean squared error was used for the image regression task. Results confirmed the feasibility of using implicit networks for breast mass segmentation and other tasks leveraging learned associations between latent codes and image/mask appearances. However, the proposed method achieved lover performance compared to deep learning methods utilizing transfer learning with models pre-trained on large scale datasets.

Although still in their infancy compared to convolutional models, implicit networks offer a promising approach to breast mass image analysis. Our study is an important preliminary step exploring the usefulness of implicit networks in US image analysis.

Acknowledgement

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