Probabilistic Pseudohealthy Synthesis of Aortic Root Shapes using Shape Primitives in Latent Space

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Aim: The synthesis of pseudohealthy images based on the pathological anatomy gained importance in computer assisted interventions, e.g. in personalized shaping of implants. One example is pre-operative planning of valve-sparing aortic root reconstruction. Previously published approaches are very limited in their variety of possible shape deformations. In this work, we present shape primitives in latent space for probabilistic pseudohealthy synthesis.

Methods: Following previously published methods, we first encode healthy and dilated shapes into a latent space using a semi-supervised variational autoencoder. In the latent space, the deformation modeling problem reduces to finding a good translation. Previous methods applied the same fixed translation vector to all samples. We propose to train a neural network in a supervised way to estimate this translation for each sample individually. In addition to this, we propose to approximate the healthy shape distribution in latent space with radial basis functions, referred to as shape primitives. Instead of estimating the translation, the network maps to the activation of these shape primitives, resulting in a high robustness and a probabilistic prediction model, i.e. the mapping from a pathologic shape image to a distribution of possible healthy shapes. From this distribution, possible candidates can be sampled, and images of these candidates can be synthesized. We evaluated this method on a dataset of ultrasound images of 24 ex-vivo porcine aortic roots in a pathologically dilated state where the ground truth is known.

Results: Our approach outperformed the fixed translation approach by 42,52% regarding the RMSE between the synthesized image and the ground truth and showed a remarkable robustness. As the proposed method is generally applicable to a wide range of organs and applications and releases the final decision making to the human expert due to its probabilistic nature, it could present an important step towards intelligent assistance in medical interventions.