# Quantitative Medical Image Synthesis for Fine-Grained Musculoskeletal Analysis from a Plain X-Ray Image

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Abstract

Image synthesis is one of the important fields in computer vision. Recent studies have focused on visual image synthesis that tries to create visually realistic images (e.g., generating X-ray images from a random vector); however, the potential for clinical applications to solve real-world problems is still limited. On the other hand, quantitative image synthesis aims to integrate metrics (e.g., tissue density and blood flow) into image synthesis from which clinical parameters can be inferred.

This work focused on developing quantitative image synthesis algorithms to achieve fine-grained musculoskeletal analysis using an X-ray image, which is a ubiquitous medical modality. Our methods achieved accurate estimations of bone mineral density (BMD), muscle mass and volume, and 3D bone shape. We first explored the X-ray image decomposition to reveal anatomical structures from an X-ray image, where we applied gradient-correlation loss to constrain the structural consistency between the X-ray image and synthesized anatomical object images. We further proposed synthesizing mass and volume distribution maps from an X-ray image to quantify muscle mass and volume with proposed intensity-summation loss. Synthesizing the BMD distribution map allowed us to obtain clinical BMD values from an X-ray image using limited training datasets. Our experiment results showed that high image resolution with appropriate pretraining could further boost the accuracy of quantitative image synthesis. To efficiently model 3D bone shape from a 2D X-ray image, we proposed dual-depth estimation, where the quantitative depth maps of front and back faces were obtained from an X-ray image and used to reconstruct bone shape in 3D with high accuracy. These achievements by our methods suggested a high clinical potential for large-scale screening of musculoskeletal diseases.