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Organ segmentation of male pelvic CTs with large artifacts caused by femoral bone prostheses

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Image artifacts are common in computed tomography due to bone prosthetics, fiducial markers and other surgical implants. These cause large changes in the image due to the way X-rays are absorbed and transmitted by the metal. Although there have been considerable advances [1], the algorithms used in image reconstruction are often unable to remove the resultant cones of shadow and high intensity streaks. In these cases, image analysis becomes very difficult. Organ segmentation must rely on shape prior knowledge and subtle cues from the whole slice and adjacent slices.

We collected 93 CT scans of patients who underwent radiotherapy for prostate cancer, all of whom had previously been implanted with femoral head prosthetics. There were 24 patients with bilateral prostheses, which exhibit particularly bad CT scans, with regions of complete shadow. The goal was to perform segmentation of prostate, bladder and rectum, essential for radiation treatment planning. The scans were manually segmented by medical experts, used as ground-truth. The dataset was split 80/13 for training/validation, and 6 in the validation set had bilateral prostheses.

We trained a three-dimensional fully convolutional neural network with an encoder-decoder architecture using dilated convolutions cascades in the skip pathways connecting the encoding and decoding arms. Dilated convolutions have the benefit of increasing the receptive field of the network without increasing computational complexity too much [2]. Furthermore, they help to extract useful information at different scales, from the finer details in organ boundaries to overall organ shape features.

Despite poor image features, the results are promising, with volumetric Dice scores of 80.1%, 94.4%, and 81.6% and average boundary distances (ABD) of 2.31mm, 1.07mm, and 2.22mm for prostate, bladder and rectum, respectively. This is an improvement over the results achieved by a 3D implementation of the original U-net [3]: Dice 77.3%, 92.4%, and 73.0% and ABD 2.62mm, 1.52mm, and 3.48mm.

Although far from a complete solution, this study shows that a properly trained, well designed deep learning model can elicit the overall shape of the organs and learn to disregard conflicting image artifacts to achieve good segmentations. Further improvements in network architecture, use of a larger training sets, and other training techniques are expected to lead to even better outcomes.

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References:

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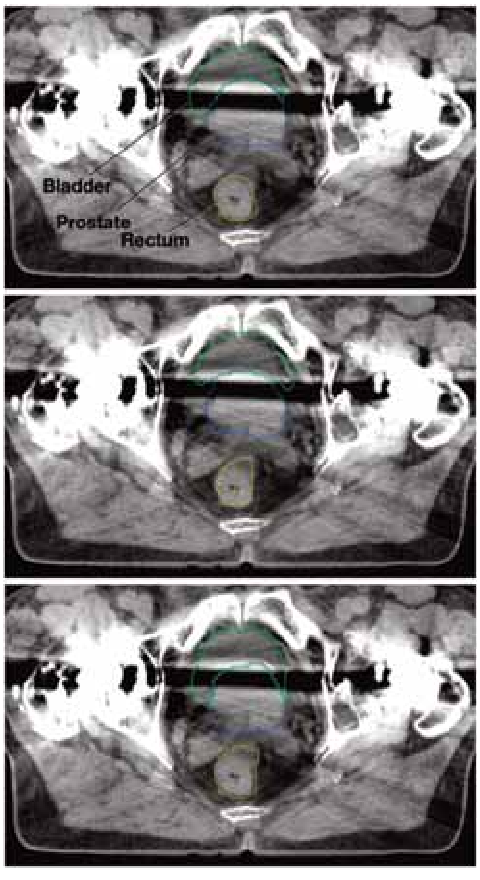

Figure caption: Example CT slice of patient with bilateral prostheses. Top: ground-truth, middle: U-net, bottom: our model.