SUPPLEMENTARY MATERIALS

Convolutional Neural Network (CNN) Algorithm Development

Datasets for Model Development

For development and validation of the model, preoperative chest CT scans obtained before surgical resection of primary lung cancer between June 2010 and June 2016 were searched from the electronic medical records of our hospital. CT was performed using a SOMATOM Definition AS (Siemens Healthineers, Forchheim, Germany). All CT datasets were divided into four categories according to the radiation dose (standard or low-dose) and the use of contrast enhancement (contrast-enhanced or not), and 25 patients were randomly selected from each category. Eighty-eight patients were randomly selected (22 from each category) to train the CNN model, while the remaining 12 patients (three from each category) were used to validate the model performance.

Development of the CNN Architecture

The super-resolution (SR) algorithm for CT slice thickness is aimed at improving the resolution only in the depth direction, which can be interpreted as spatial information in the coronal and sagittal planes. The SR network is divided into preprocessing, non-linear mapping, and reconstruction parts (Fig. 2).

The preprocessing part, which handles variance from input images with different scales, is composed of two residual blocks (resblocks) with a 5 x 5 kernel and 64 channels, one for 3-mm and the other for 5-mm slice thicknesses. The non-linear mapping part consists of two long concatenation units, both of which have four resblocks with a 3 x 3 kernel and 64 channels. The reconstruction part uses a 3 x 3 convolution layer and a subpixel shuffling layer to expand the number of axial images by 3 or 5 times in the depth direction.

The SR network has two main characteristics. The first characteristic is the ability to be trained on the differences between low-resolution input images (3 or 5 mm) and target images (1 mm), with the inverse function of subpixel shuffling being used to convert the label image into a low-resolution image. The second characteristic is that all convolution layers are in three-dimensional and no batch normalization layer is employed to improve performance.

The prepared image database was fed into the deep learning processing server, which was created using a Linux operating system (Ubuntu 14.04; Canonical, London, England), the Pytorch deep learning framework (https://pytorch.org), and CUDA 8.0/cuDNN 5.1 dependencies (Nvidia Corporation, Santa Clara, CA, USA) for graphics processing unit acceleration. The computing server had an Intel Xeon E5-2620 processor (Intel, Santa Clara, CA, USA), 256 GB of RAM, and eight NVIDIA GTX Titan Xp (NVIDIA Corporation) graphics processing units.

All CT scans were successfully converted to 1-mm slice images at a rate of 2.5 s/slice, and about 3–4 minutes for one full chest CT dataset.