G-012

Attenuation Correction Factors Generation of a Dedicated Brain PET System with Time-of-Flight Information Using a High-resolution Compact Network

Tuo Yin‡ Takashi Obi‡

1. Introduction

Early diagnosis of dementia has become an urgent issue due to the aging society. A dedicated brain positron emission tomographic (PET) system which can be expected to generate images of the accumulation status of specific proteins in the brain that are the causative agents of Alzheimer's disease is currently under development, solving problems such as the size and cost of whole-body PET/CT devices [1].

In conventional PET/CT devices, the attenuation information is obtained by a well-aligned CT device, which decides attenuation correction factors (ACF) of every single pixel and apply the factor to activity maps. It improves activity intensity due to radiation attenuation induced by dense materials in patients' brain. However, the dedicated brain PET system is not supposed to use a CT device because of the size, cost, etc. Therefore, a reliable approach for ACF acquisition without aligned CT is highly desired. Maximum likelihood attenuation correction factors (MLACF), a simultaneous reconstruction algorithm, has the advantage of providing ACF directly from time-of-flight (TOF) PET emission data without prior information on the attenuation to reconstruct activity maps by applying ACF to the activity map in each iteration, it suffers from slow convergence, high computational and time complexity [2].

In this work, a novel approach is proposed to estimate ACF sinogram directly from TOF PET emission data using a deep neural network.

2. Materials and Methods

We used 20 anatomical models from the BrainWeb database to create PET emission data. Each subject model consists of a set of 3D tissue membership volumes including 11 tissue classes. We created activity and attenuation maps served as the ground truth depending on the tissue classes of each voxel. We converted the 3-D volumes into 2-D slices and added five patterns of random activity to activity maps. TOF sinograms and ACF sinograms were generated using forward projection from each pair of ground truth activity and attenuation map. TOF sinogram was organized in five sinograms and each sinogram was for one TOF bin. Poisson noise was added to the noise-free TOF sinograms to simulate PET emission data in the real case. 15,1, and 4 anatomical models were in the training, validation, and testing dataset, respectively. Three samples of the training data are plotted in Fig. 1.

A modified high-resolution compact network is utilized to estimate ACF sinogram from TOF sinograms, as shown in Fig. 2. It consists of 20 convolutional layers with 3×3 kernels, inspired by a compact network for volumetric image segmentation [3]. The first 7 layers are designed to extract low-level features. The following 6 and 6 layers are used to encode middle and high-level features with a dilated factor of 2 and 4. The last convolutional layer use 1 kernel and output a ACF sinogram. Different from the compact network, we concatenate the features between two convolutional layers instead of simply add them together to preserve more features in the earlier stage. We use 2-D 3×3 kernels instead of 3-D larger kernels to reduce parameters and accelerate the convergence of the model. The dilated factors are added to enlarge the receptive field and generate high-resolution features.

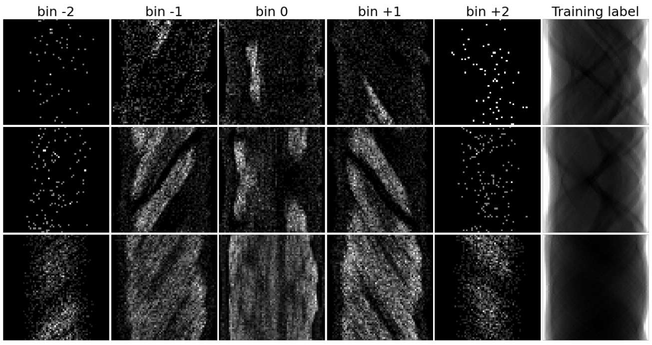

Fig. 1 Three representative cases of TOF sinograms and training labels

The network was implemented using Tensorflow 2.0 platform. The mean squared error (MSE) between the prediction and label was selected as the loss function. The modified high-resolution compact network was compared with MLACF algorithm with 50 iterations. For quantitative evaluation, we select normalized root mean square error (NRMSE), structural similarity index measure (SSIM), and peak signal-to-noise ratio (PSNR) for comparisons. In order to observe the attenuation

† Department of Information and Communications Engineering, Graduate School of Engineering, Tokyo Institute of Technology
‡ Institute of Innovative Research, Tokyo Institute of Technology

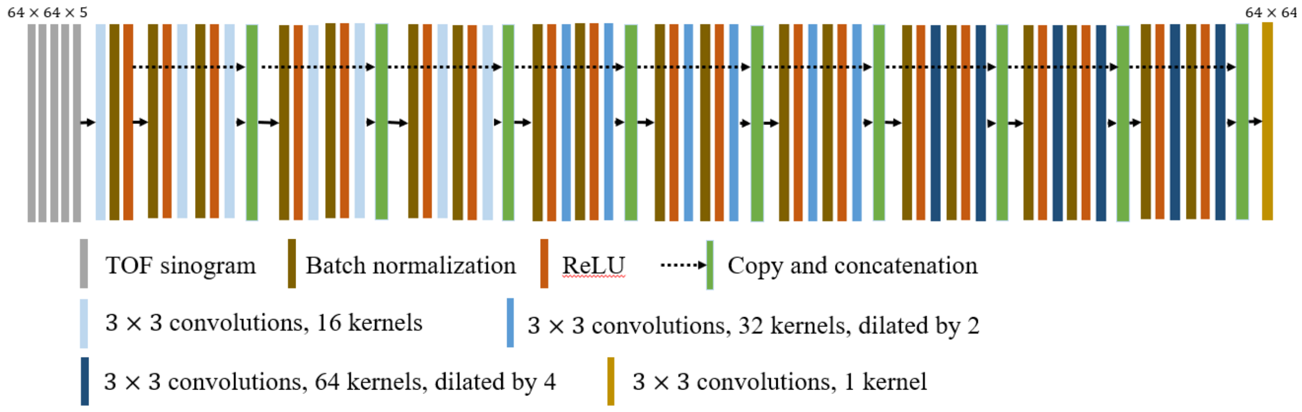

Fig. 2 High-resolution compact network architecture for ACF generation

coefficients in image space, we use the predicted ACF as inputs of maximum likelihood expectation maximization (MLEM) algorithm to reconstruct the attenuation map.

3. Results

As shown in Fig. 3 and Table 1, the proposed method with TOF sinograms as inputs demonstrates superior performance compared with MLACF and using projections without TOF information. From qualitative

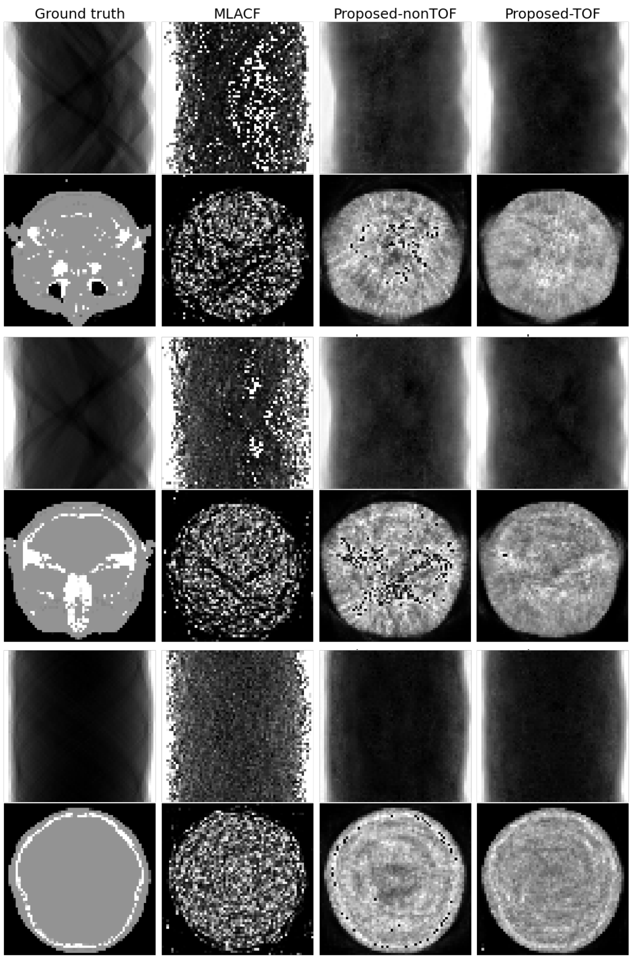

Fig. 3 Three predictions using different methods

results, we observe that our approach is capable of predicting attenuation coefficients closer to the ground truth, while both ACF and attenuation map of MLACF have a high level of noise. Additionally, this approach achieves the lowest error with a NRMSE of 0.08 and the highest image quality of ACF with a SSIM of 0.95 and a PSNR of 30.95 dB, as indicated in Table 1.

Table 1 NRMSE, SSIM and PSNR comparisons

	NRMSE	SSIM	PSNR
MLACF	0.48	0.37	14.55
Proposed-nonTOF	0.16	0.92	25.17
Proposed-TOF	**0.08**	**0.95**	**30.95**

4. Discussion and Conclusion

From data analysis, we find that the modified high-resolution compact network with TOF information predicts ACF more precisely. The ACF predictions of our approach can be applied to other reconstruction methods as complementary information.

In a dedicated brain PET system, an accurate ACF generation approach is highly desired in the absence of concurrent CT scanning. In this work, different TOF sinogram bins pertinent to the same slice are fed into a modified high-resolution compact network to estimate a single ACF sinogram associated with the same slice. Compare with MLACF, the proposed method achieves a lower NRMSE and a higher SSIM and PSNR.

References

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