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► **To cite this version:**

Ishak Ayad, Cécilia Tarpau, Mai K Nguyen. Tomographic image reconstruction from incomplete data via a hybrid GAN. Nuclear Science Symposium, Medical Imaging Conference and Room Temperature Semiconductor Detector Conference, Nov 2022, Milano, Italy. hal-03780132

HAL Id: hal-03780132

<https://hal.science/hal-03780132>

Submitted on 19 Sep 2022

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Tomographic image reconstruction from incomplete data via a hybrid GAN

Ishak Ayad, Cécilia Tarpau, and Mai K. Nguyen, Senior Member, IEEE

Abstract—Limited data tomographic reconstruction has been widely used in medical imaging to reduce the radiation dose or shorten the data acquisition time. This is achieved by truncating the scanning angular range or increasing the angular sampling rate. However, the use of classical reconstruction methods with such incomplete data involves severe streaking artifacts, blurred edges, distorted boundaries, contrast loss, and decreased intensities in the reconstructed images. In this work, we propose a generative adversarial network made of a V-net generator with modified skip connections that simulates the algebraic reconstruction and a discriminator combining both information from the image and projection domains which only penalizes structure at the scale of image patches. The proposed method obtains promising results for data coming from both limited-angle and sparse-view projections, that is, data acquired from an angular range of 90 degrees and an angular sampling step of 10 degrees.

Index Terms—computed tomography, generative adversarial networks, hybrid representations

I. INTRODUCTION

COMPUTED tomography relies on the collection of data using transmitted X-rays taken from different angles after they passed through the object under study. Then, from this set of data, the most known reconstruction technique is the filtered back-projection (FBP) works efficiently with a complete set of data, that is for an angular domain $\phi \in \Phi = [0^\circ, 180^\circ[$ with a sampling step $\Delta\Phi \leq 1^\circ$. Nevertheless, in some practical situations, these conditions cannot be respected, and the angular domain is truncated and/or sparse. we denoted in the rest of the paper Φ_a the available angular domain. In such scenarios, reconstructions from FBP algorithm will contain severe streak artifacts and distortions. Those missing data problems were first tackled with optimization techniques, such as the Tikhonov regularization. Recently, with the success of deep learning limited data CT image reconstruction reached another level using learning approaches, especially hybrid deep neural networks [1], [2] combining both information of the image and projection domains. Here we propose a new hybrid generative adversarial network called Rad2Pix, which includes the advantages of a hybrid network in a GAN architecture. We

will show that this network is able to reconstruct objects from sparse or limited-angle data, as well as with scenarios where we are faced in both problems in the same time.

II. RAD2PIX : AN ARCHITECTURE CONVENIENT FOR LIMITED-ANGULAR AND SPARSE-VIEW CT RECONSTRUCTION

The proposed network (see Fig. 1) is a patchGAN Pix2Ppix architecture [3] where the generator (G) is a V-net and the discriminator (D) is a patchGAN. The particularity of this architecture lies in its ability of mapping data (Radon domain) to the image domain at different scales to extract the important features. This connection is ensured by the skip connection blocks of the V-Net, made of fully connected layers. The aim here is to mimic a least-squares minimization problem, as showed in [4]. The PatchGAN discriminator also acts on both domains.

The loss function used to train Rad2Pix is a mean of the binary cross entropy (BCE) and the structural dissimilarity index.

$$L_{bce} = \log(D(I_r \oplus S_c)) + \log(1 - D(G(S_m) \oplus S_m)) \quad (1)$$

where \oplus is the concatenation operation, S_m is the incomplete sinogram, I_r is the original image and S_c its complete sinogram.

III. NUMERICAL EXPERIMENTS AND RESULTS

For our experiments, we used 7300 images of a clinical dataset called Phantom FDA from the cancer imaging archive [5]. The size of the images is $N^2 = 128 \times 128$ pixels. We performed sinogram acquisitions with several limited-angle and sparse-view scenarios. These sinograms will be used as inputs for Rad2Pix training. The scenario and the amount of missing data for each original image is chosen randomly. We give in Table I some critical scenarios, where our method still gives good reconstruction results, whereas other previous techniques such as [4] fail. See also Fig. 2) for a qualitative comparison of one obtained result with Rad2Pix with FBP and [4].

IV. CONCLUSIONS

We demonstrate that the Rad2Pix provides high-quality reconstructions from both limited and/or sparse data. In practical scenarios, the use of such reconstruction method allows reducing radiation dose and shortening scanning time. Future works will consist in studying the robustness of such architecture on more realistic data with Poisson noise.

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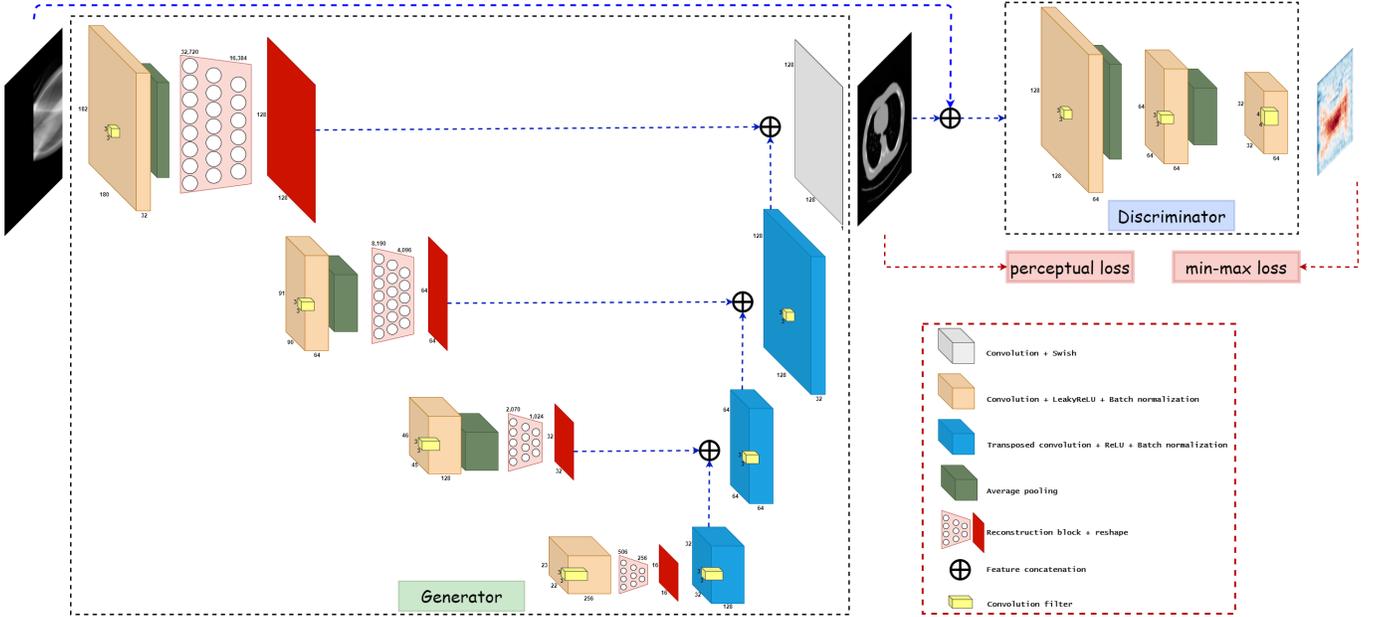


Fig. 1: Structure of the overall proposed Rad2Pix method for artifact suppression and CT image reconstruction.

Angular domain	Method	FBP		Tikhonov		Würfl [4]		Rad2Pix	
		PSNR	SSIM	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM
$\Phi_a = [0^\circ, 90^\circ], \Delta\Phi_a = 1^\circ$		13.7	0.34	17.5	0.30	17.2	0.29	30.4	0.94
$\Phi_a = [0^\circ, 180^\circ], \Delta\Phi_a = 10^\circ$		12.2	0.38	21.5	0.33	22.2	0.45	30.2	0.97
$\Phi_a = [40^\circ, 150^\circ], \Delta\Phi_a = 10^\circ$		11.1	0.28	17.2	0.25	15.4	0.21	32.1	0.94

TABLE I: Mean PSNR and SSIM values of reconstruction results obtained from FBP algorithm, Tikhonov regularization, Würfl [4] and Rad2Pix.

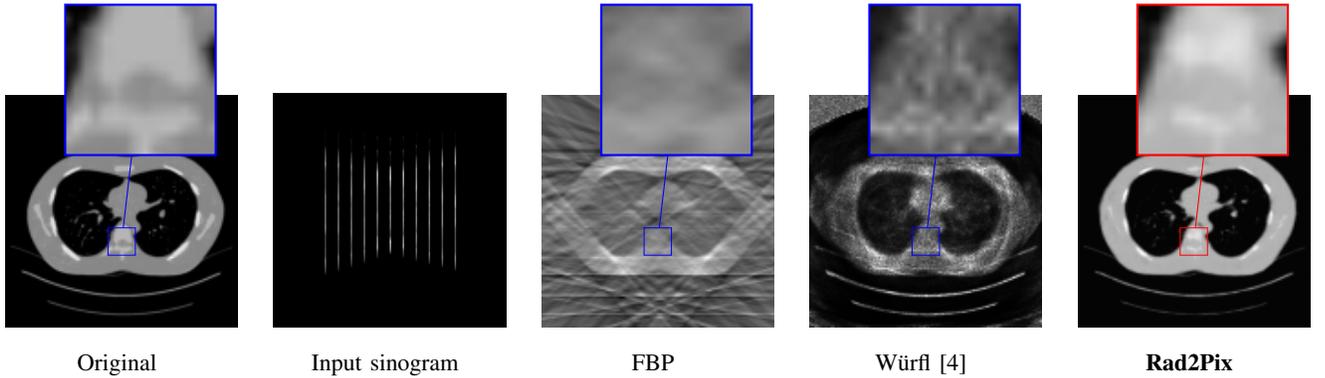


Fig. 2: Reconstruction results obtained with limited-angle CT where $\Phi_a = [50^\circ, 140^\circ]$ and $\Delta\Phi_a = 10^\circ$ (11 projections). From left to right columns : results obtained with FBP, [4] and Rad2Pix.

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