Robustness evaluation of a neural network-based deconvolution method of ion chamber-measured photon beam profiles

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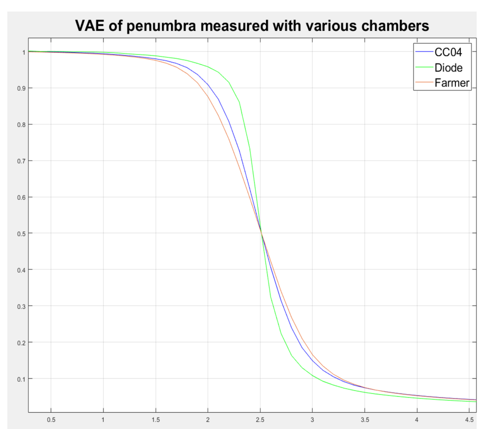
INTRODUCTION

The volume averaging effect (VAE) of ion chamber (IC) has been a long standing issue in medical physics. Using machine learning technique, we found a clinically feasible solution to address the issue. The authors have previously shown that neural network (NN) can successfully perform photon beam profile deconvolution--the elimination of volume average effect (VAE) of scanning ionization chambers (IC). Here we evaluate the robustness of the technique when applied to various ICs and beam modalities.



AIM

Evaluate the robustness of a neural network-based deconvolution method for the of ion chamber-measured photon beam profiles by applying it to various ICs and beam modalities. The network can correct for the VAE from IC measurements for profiles of multiple field sizes measured at different depths for FF and FFF modalities

METHOD

The proposed NN has an input, hidden and output layer. It inputs data extracted from cross beam profiles using a sliding window (SW), and outputs deconvolved data at the center of the window. Cross beam profiles of fields ranging from 2x2 to 10x10 cm2 were measured with CC04, CC13, Farmer chamber and an EDGE diode detector for 6 MV FF and FFF beams. The profiles measured with each chamber were divided into training, validation, and testing sets to train and test a 3-layer feed forward NN. The diode-measured data was used as the reference. The sliding window length and the number of hidden neurons were optimized such that the same NN structure be applied for all tested chambers, fields, depths, and beam modalities. The NN's performances were quantified by evaluating mean square error (MSE) and penumbra width difference (PWD) between the deconvolved and EDGE-measured profiles.

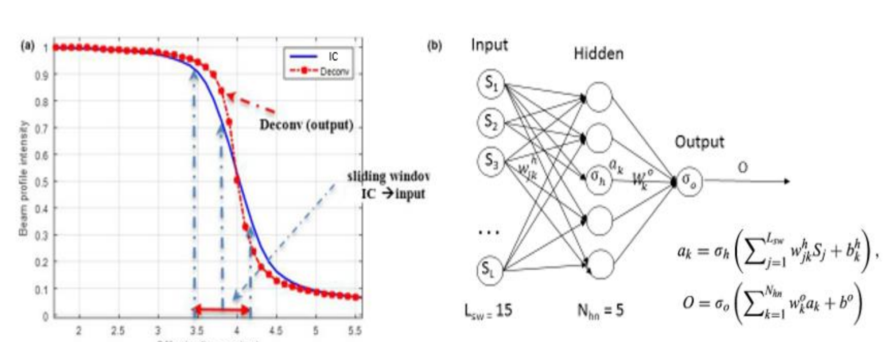
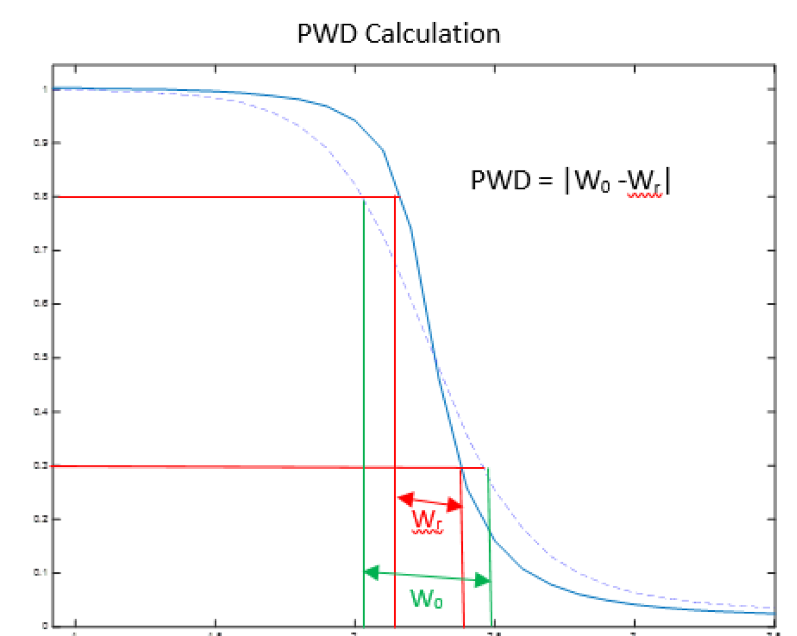


Fig. 1. Schematic plot of the structure of the neural network receiving the SW input from the photon profile and the deconvolved output

RESULTS

Excellent agreement between the deconvolved and reference profiles was achieved using a sliding window width of 15 and 5 hidden neurons for all the tested ICs and both beam modalities. The average PWD decreased from 2.70±0.47, 2.66±0.41, and 3.99±0.42 mm to 0.09±0.39, 0.03±0.35, and 0.04±0.38 mm for the CC04, CC13, and Farmer chambers, respectively.



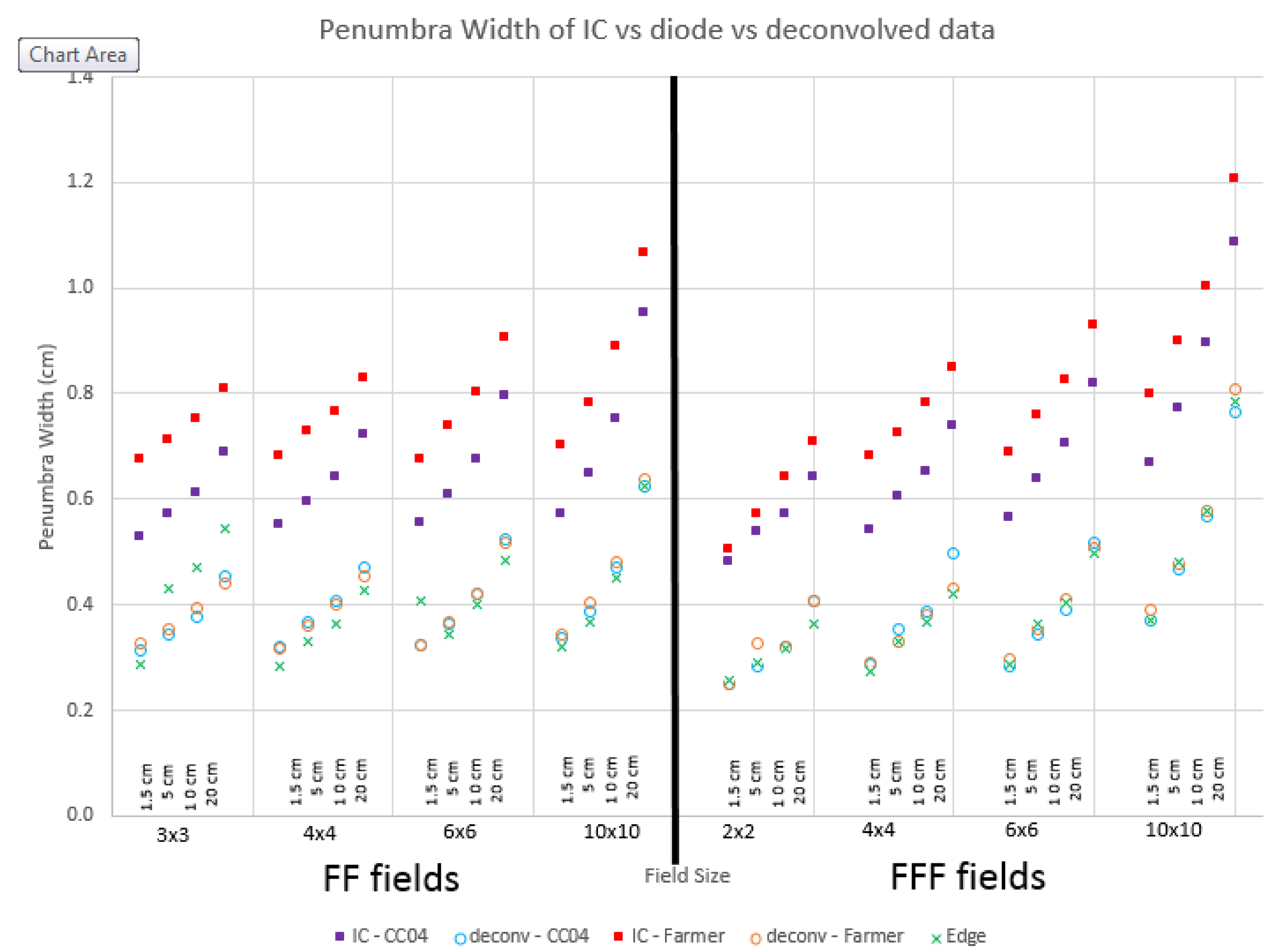


Fig. 2. (right) Formula for Penumbra Width Difference – difference between the distance between the 20-80% intensity between chamber measured and diode measured profiles. Penumbra width difference shows whether the deconvolution method was able to restore the sharpness to the penumbra region of the profiles. (left) IC penumbra widths (red and purple squares) are shown compared to the penumbra widths of the reference diode profiles (green X) and deconvolved profiles (orange and blue rings).

		PWD for training with individual modality data vs combined modality data							
		CC04 FF				Farmer FF			
		FF only		FF + FFF		FFF only		FF + FFF	
	depth(cm)	CC04 FF	deconv	CC04 FF	deconv		deconv		deconv
5x5	1.5	2.5	0.3	2.5	0.3	3.8	0.3	3.8	0.0
	5	2.5	0.2	2.5	0.3	3.8	0.2	3.8	0.1
	10	2.7	0.3	2.7	0.4	3.9	0.2	3.9	0.1
	20	3.1	0.6	3.1	0.7	4.2	0.3	4.2	0.2
8x8	1.5	2.5	0.2	2.5	0.2	3.8	0.3	3.8	0.1
	5	2.8	0.3	2.8	0.4	4.0	0.2	4.0	0.0
	10	2.8	0.1	2.8	0.2	4.0	0.2	4.0	0.0
	20	3.2	0.2	3.2	0.4	4.3	0.2	4.3	0.3
	AVG (mm)	2.76	0.28	2.76	0.36	3.98	0.24	3.98	0.10

		PWD for training with individual modality data vs combined modality data							
		CC04 FFF				Farmer FFF			
		FF only		FF + FFF		FFF only		FF + FFF	
	depth(cm)	CC04 FF	deconv	CC04 FF	deconv		deconv		deconv
5x5	1.5	2.5	0.0	2.5	0.2	3.8	0.2	3.8	0.2
	5	2.5	0.1	2.5	0.0	3.8	0.0	3.8	0.2
	10	2.7	0.0	2.7	0.1	3.9	0.1	3.9	0.2
	20	3.1	0.4	3.1	0.2	4.2	0.2	4.2	0.0
8x8	1.5	2.5	0.4	2.5	0.1	3.8	0.3	3.8	0.2
	5	2.8	0.1	2.8	0.4	4.0	0.1	4.0	0.0
	10	2.8	0.4	2.8	0.2	4.0	0.1	4.0	0.3
	20	3.2	0.2	3.2	0.1	4.3	0.4	4.3	0.3
	AVG (mm)	2.76	0.20	2.76	0.16	3.98	0.18	3.98	0.18

Table. 1. Table of PWD for IC-measured profiles and deconvolved profiles with respect to the reference diode-measured profiles for networks trained with only single or combined modality data.

CONCLUSIONS

We found that the NN-based deconvolution method can be effectively applied to ICs of various sizes and beams of different modalities. Separate NNs are needed for different ICs but, for a specific IC, one NN works for both beam modalities.

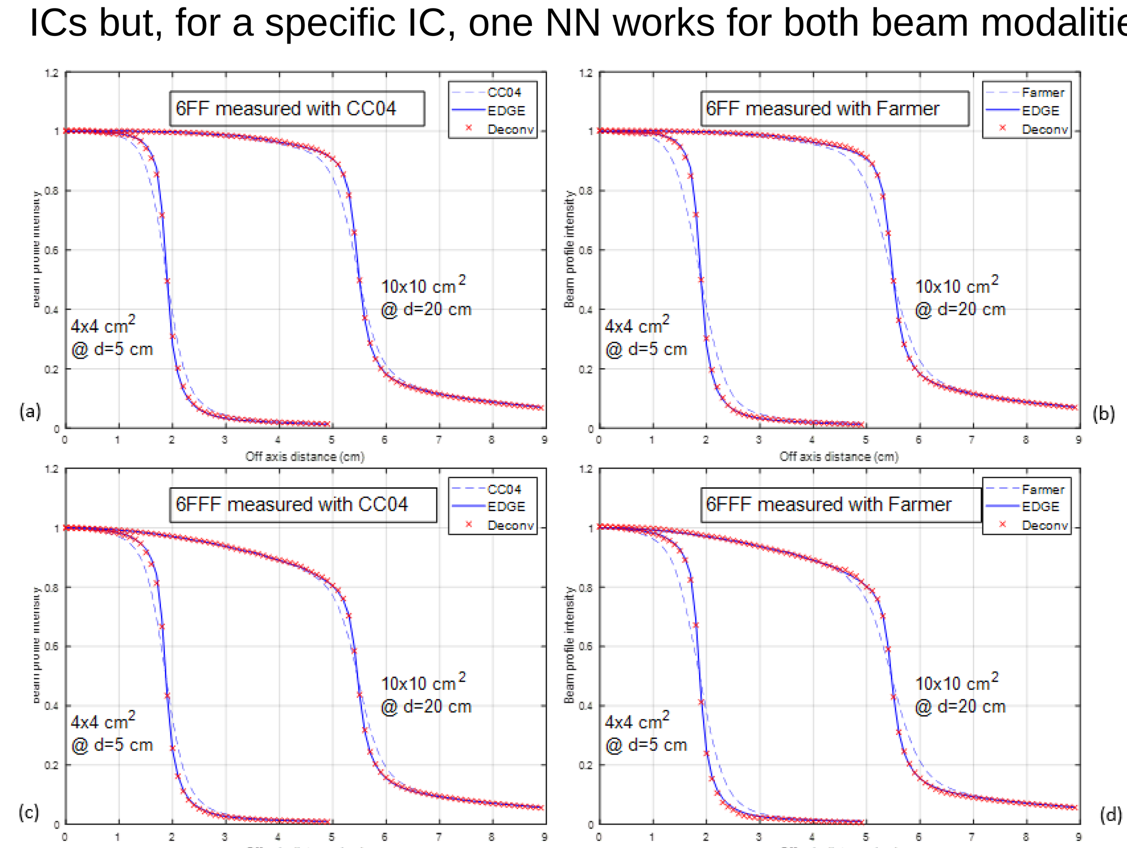


Fig. 4. Plots of deconvolved profiles showing good agreement with the diode reference profiles for different IC measurments of FF and FFF modalities

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