Supplementary information for High-resolution and reliable automatic target recognition based on photonic ISAR imaging system with explainable deep learning

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S1. Experimental setup of photonic ISAR imaging system

Figure S1 displays the experimental setup of a photonic ISAR imaging system. The receiver is a photonic analog-to-digital converter (PADC) system which can receive high frequency and big bandwidth RF signals without complex operation of frequency mixing. In our experiment, the antennas (Tx and Rx) look down the target. The target is fixed on a rotation table which rotates in the counterclockwise direction.

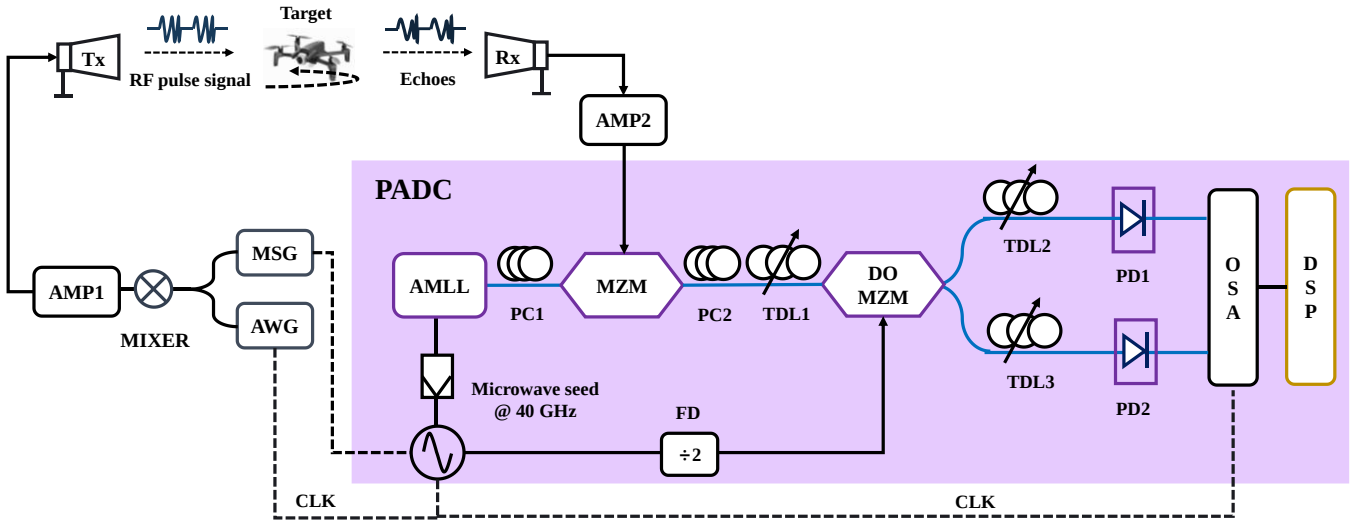

Fig. S1 The experimental setup of photonic ISAR imaging system. The architecture of PADC is highlighted with purple fill box. Tx: transmitting horn antenna; Rx: receiving horn antenna. AWG: arbitrary waveform generator; MSG: microwave signal generator; AMP: amplifier; AMLL: actively mode-locked laser; PC: polarization controller; MZM: Mach-Zehnder modulator; TDL: tunable delay line; DOMZM: dual-output Mach-Zehnder modulator; PD: photodetectors; FD: frequency divider; OSA: oscilloscope; DSP: digital signal processing; CLK: the reference clock.

S2. The result of three post-hoc interpretability technologies

We use three interpretability technologies to exploit how the CNN_8 recognizes different targets. In Fig. S2, the results of the DTD, IG, and LRP reflect the relevance between pixels of ISAR images and the outcome of network recognition. The larger the relevance is, the brighter the corresponding pixel is highlighted. Comparing the results of the DTD with their corresponding ISAR images, we can see that the CNN neglects many unimportant pixels which depict the surfaces of targets and depends on many pixels which depict the contours of targets to recognize different targets. The values of the results of the DTD are always positive due to the property of the DTD's principles which is illustrated in Ref.[37]. Thus, the results of the DTD reflect the influence of input features. Whereas we do not know it is positive or negative. The results of the IG and LRP are almost same. Among these results of interpretability, we roughly sketch the contours of the pixels highlighted by yellow color via the white dotted lines. The white contours largely outline the shape and structure of targets. This indicates that the CNN_8 distinguishes different targets according to their shapes and structures and confirms the credibility of the interpretability results by the LRP.

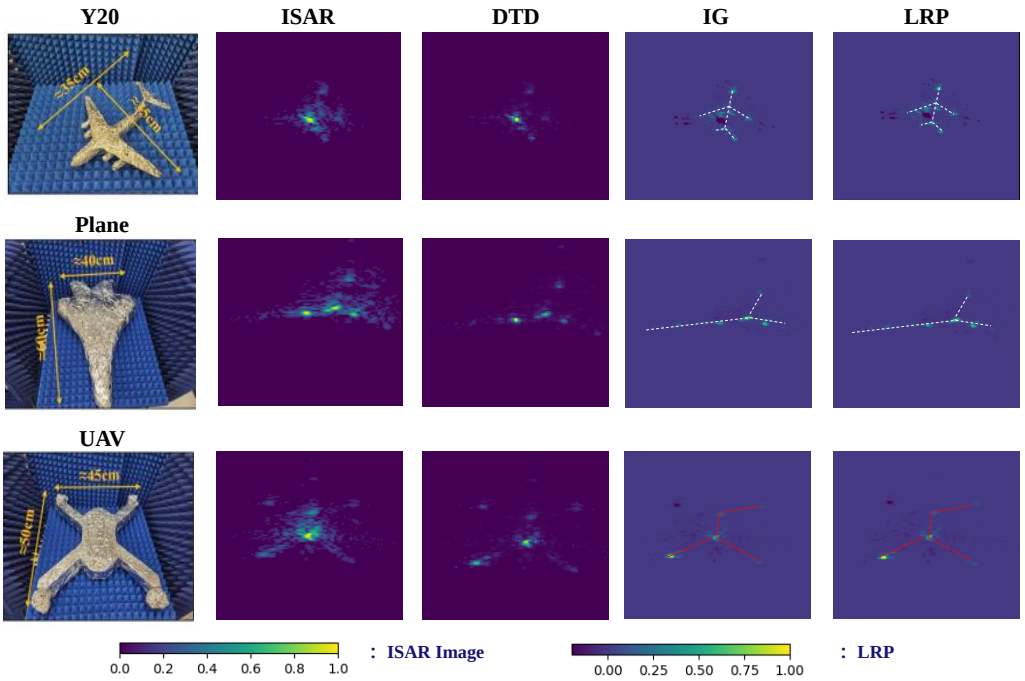

Fig. S2 Results of three post-hoc interpretability technologies. IG: Integrated Gradient[36]; DTD: Deep Taylor Decomposition[37] (DTD); LRP: layer-wise relevance propagation (LRP)[35].

S3. The loss and accuracy curves of the CNNs

We use ISAR images of three targets, each target 50 examples, obtained under the bandwidths of 4 GHz and 8 GHz to train two CNNs. The two CNNs trained with ISAR images under 4 GHz and 8 GHz are named as CNN_4 and CNN_8, respectively. From Fig. S4, we can know that both the CNN_4 and CNN_8 are well converged and without overfitting. The testing losses of the CNN_4 and CNN_8 decrease to 0.76 and 0.17, respectively. The testing accuracies of the CNN_4 and CNN_8 are 87.78% and 96.00%, respectively.

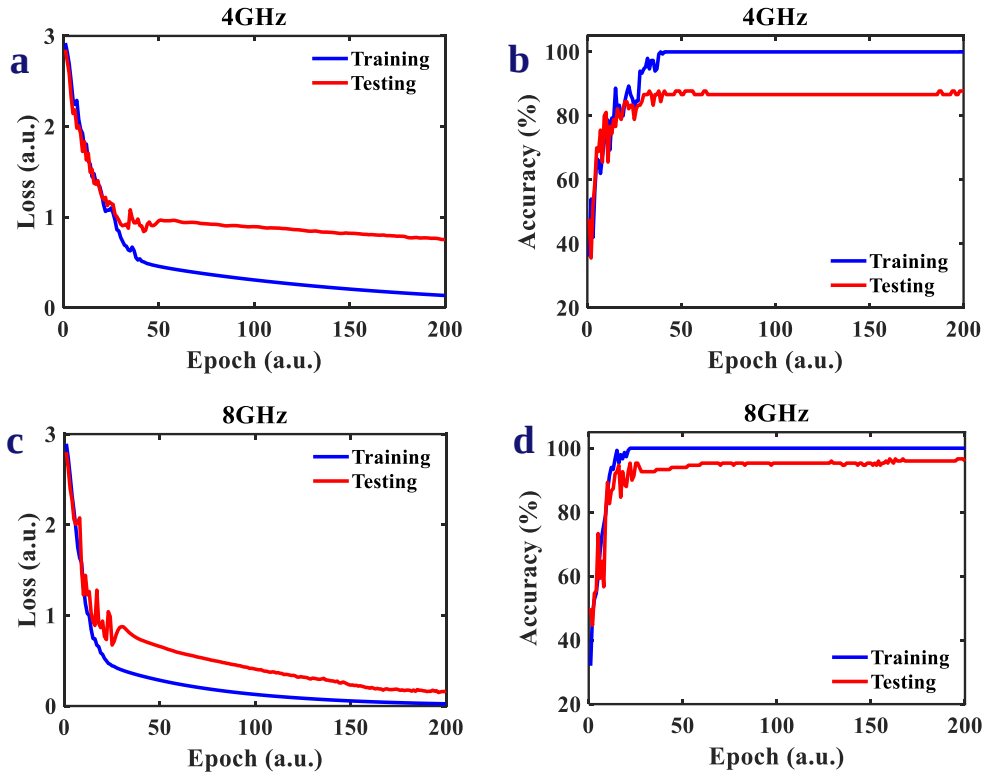

Fig. S3 The loss and accuracy curves of the CNN_4 and CNN_8. a, b, The loss and accuracy curves of the CNN_4. **c, d,** The loss and accuracy curves of the CNN_8. The testing loss of the CNN_8 decreases to smaller values than that of the CNN_4 at the same epochs. The testing accuracy of the CNN_8 is higher than that of the CNN_4.