2^{nd} *URSI AT-RASC, Gran Canaria, 28 May – 1 June 2018*

Dynamic Feature Extraction Using Reprogrammable Coding Metasurface

Lianlin Li* (1)
(1) Peking University, Beijing, 100871, e-mail: lianlin.li@pku.edu.cn

Driven by the development of reprogrammable metasurface, we realize the dynamic feature extraction using reprogrammable coding metasurface in this work for the first time. The targets here are images of three-dimensional human body with the constant contrast of 13 (see Fig. 1a), and we could recognize and classify them using the extracted feature. The scenario could be described like that, the target is illuminated by the radiation field of programmable coding metasurface, and then the scattered field of the target would be recorded by a single detector. The fundamental mathematical expression is $\boldsymbol{y} = \mathbf{W}^{\mathrm{T}}\boldsymbol{x}$, where the two column vectors $\boldsymbol{x} \sim \Re^{\mathrm{M}\times 1}$ and $\boldsymbol{y} \sim \Re^{\mathrm{N}\times 1}$ represent the target images and received data, respectively, and $\mathbf{W} \sim \Re^{\mathrm{M}\times\mathrm{N}} (\mathrm{N} < \mathrm{M})$ is a dimension-reduction matrix. In fact, each column of $\mathbf{W}$ is a radiation pattern of the metasurface at the target image's position and we need to switch the coding sequence of the programmable metasurface electrically, which is easy and fast, and record the data for N times. As we known, the entries in $\mathbf{W}$ will affect the quality of classification, and different coding sequence of the metasurface results in different $\mathbf{W}$, so proper coding sequences of the metasurface need to be carefully manipulated. The reprogrammable metasurface can be trained by using the principal component analysis (PCA), a widely used method in the area of machine learning, when a collection of samples is available (see Fig. 1). As comparison (Fig. 1 and Fig. 2), we compare the classification results obtained by the reprogrammable metasurface trained by the PCA technique and random projection in Figure 2, where the idea results obtained by performing the PCA analysis are also presented. we also try the conventional way, classification after imaging reconstruction to find that it requires more data to guarantee the accuracy of the classification though using some compressive imaging methods. Actually, the average classification accuracy in our work can achieve about 80%, in which some could exceed 90%, and we can improve some numbers' accuracy according to practical needs with a compromise of other numbers. In addition, some influence factors on the classification accuracy like scale of the metasurface, the amount of received data, just the switching times of the metasurface, namely the dimensional-reduction ratio of object images, have been taken into consideration.

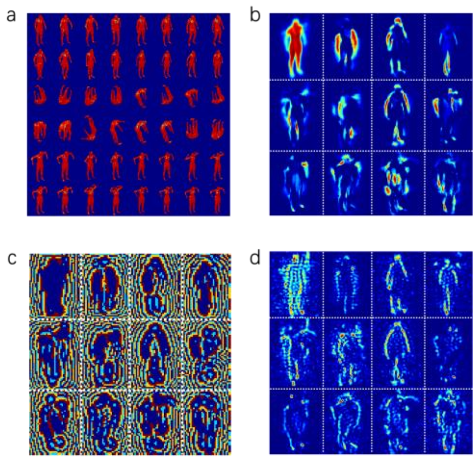

Fig. 1(a) Some of the human body samples. (b) The 12 ideal leading PCA bases. (c) The corresponding coding distributions on the programmable metasurface. (d) The radiation patterns generated by coding patterns.

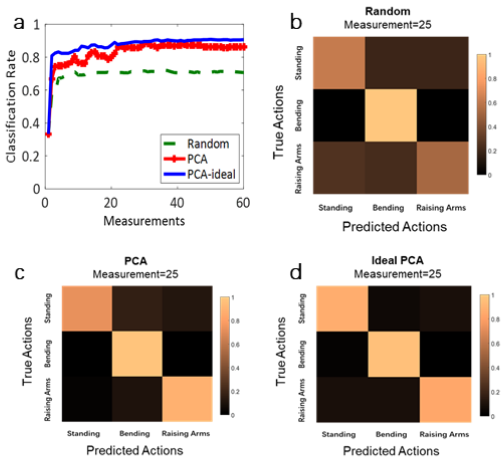

Fig. 2((a) The classification rate versus the number of measurements when the programmable metasurface is trained by random projection and PCA. For comparison, the corresponding results by the theoretical PCA (blue line) are also provided. (b) The comparison of specific classification results by the random projection, PCA, and theoretical PCA, in which 15 measurements are used.