Super-resolution Block-wise Compressive Imaging and its Binary Sensing Matrices Design

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1. Introduction

In applications such as IR imaging, sensors have poor resolutions due to industry manufactory limitation. To obtain high resolution images, we studied block-wise compressive imaging (BCI). However, a BCI system resolution is limited by the resolution of a spatial light modulator such as a DMD (Digital Micro-mirror Device). To overcome this restriction, we use subpixel shift super-resolution idea with BCI. We refer such a system as a super-resolution BCI (SBCI) system.

2. Theory of SBCI

In BCI, system measurement model is defined as $\mathbf{y} = \mathbf{F}\mathbf{x} + \mathbf{n}$, where $\mathbf{y}$, $\mathbf{x}$, and $\mathbf{n}$ are the measurement, object block, and noise vectors, respectively. $\mathbf{F}$ is the measurement matrix. In SBCI, the modulation of images of object blocks can be represented as Fig.1. The dish-line marked area is for one object block of size (4×4). We assume a DMD pixel is larger than an object pixel. Here a DMD mirror is for a (2×2) object pixel area. This means that, the 4 elements in a sensing vector $\mathbf{f}_i$ corresponding to one DMD mirror are same to each other. In another word, a sensing vector has constraints, such as $\mathbf{f}_i^T\mathbf{w}_j = 0$. Vector $\mathbf{w}_j$ is defined as shown in Fig.1. In SBCI, to make sub-pixel shift we can move the lens before the DMD. Then the image of an object is moving accordingly. Because the sensing vector patterns displayed on DMD are same for different blocks, the constraint patterns $\mathbf{w}_j$ will look like horizontally circularly shifted.

In our previous work[1], we found searching a binary sensing matrix for BCI is to search a matrix close to a subspace Ψ which can be represented as $\mathbf{A}\mathbf{Q}_{\mathrm{PCA}}^{\mathrm{T}}$, where $\mathbf{A}$ is any invertible matrix of size (M×M) with $\mathbf{A}\mathbf{A}^{\mathrm{T}} = \mathbf{I}$. The columns of $\mathbf{Q}_{\mathrm{PCA}}$ are the M eigen-vectors $\{\mathbf{q}_i, i = 1,\cdots,M\}$ of object auto-correlation matrix corresponding to its M largest eigen-values. For SBCI, to search a sensing matrix can still be searching a matrix $\mathbf{F}$ which is close to subspace Ψ. Then the matrix design problem becomes to solve an optimization problem as following,

$$\min_{\mathbf{A},\mathbf{F}} \ \varepsilon(\mathbf{A},\mathbf{F}) = \left\|\mathbf{A}\mathbf{Q}_{\mathrm{PCA}}^{\mathrm{T}} - \mathbf{F}\right\|_F^2$$

$$\text{subj to} \quad \mathbf{G} = \mathbf{A}\mathbf{A}^{\mathrm{T}} - \mathbf{I} = \mathbf{0}$$

$$\left\|\mathbf{F}\mathbf{W}\right\|_F^2 = 0$$

3. Experimental Results

We use eight 480×630 and ten 256×293 IR object examples for the numerical experiment. Object block size is (4×4). M = 4 sensing vectors are used to collect measurements. Linear Wiener operator is used to reconstruct objects. RMSE is used to quantify the reconstruction error. From top to the bottom, the 4 rows of Fig.2 show the designed binary sensing vectors for the original object position, for the positions with sub-pixel shift downward, shift to the right, and shift diagonally. We refer the four sets of vectors as F_or, F_dn, F_ri, and F_di. In Fig.3 and 4, we present the reconstructions using F_or only, F_or and F_dn jointly, when noise standard deviation is σ=148.7. We found visually the reconstruction using F_or and F_dn jointly has better quality.

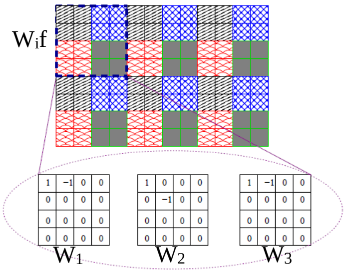

Fig.1

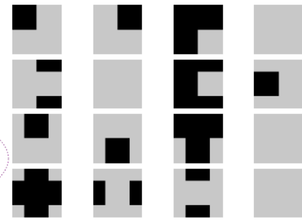
Fig.2


Fig.3


Fig.4

3. Conclusions

In this work, subpixel shift SBCI is studied to break through the resolution restriction determined by a DMD. An optimization problem is formulated, and then solved to obtain optimized binary sensing matrixes. Numerical results are presented to demonstrate our idea.

This work was supported in part by the National Natural Science Foundation of China under Project 61675023, 61307022 and 11727801.

References

[1] Jun Ke and Edmund Y. Lam, *Optics Express*, vol. 24, pp. 9869-9887, 2016.