Performance Metrics for Multi-aperture Computational Imaging Sensor

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Abstract: Determining the effective MTF, SNR and Sensor geometries of multi-aperture computational imaging architectures will allow the National Image Interpretability Rating Scale to be applied to computational imagers. An approach for determining the effective MTF is described.

OCIS codes: (110.0110) Imaging systems; (110.4100) Modulation Transfer Function

1. Introduction

Comparing the performance of multi-aperture computational imaging sensors' architectures to their traditional baseline equivalents is challenging because the computational imager performance does not stem solely from the physical configuration, but rather has some measure of computational gain associated with its performance level. Measures like mean squared error (MSE), which make computational versus traditional comparison an easy one, are not necessarily the most appropriate performance metrics. The National Image Interpretability Rating Scale (NIIRS) standard [1] proposes to quantify the efficacy of a given imaging sensor for a specific application. To aid in the design of imaging sensors, empirical equations which predict the NIIRS number for a given design have been determined. One such approach is termed the General Image-Quality Equation (GIQE) [2] . The input parameters to GIQE include attributes of the image sensor such as the system MTF, SNR, and the sensor geometry. There exist several other approaches for predicting application specific performance [3], but they all require some subset of the GIQE input parameters. It is a challenging task to model the performance of a computational imager with co-designed multi-aperture optics and adaptive image reconstruction. The goal of this paper is to provide an approach to determine the effective MTF and the effective SNR of a computational imager, based on the collection of physical imaging resources utilized and the computational gain of combining their data.

2. Computation of the effective Modulation Transfer Function

In a multi-aperture computational imager, each sub-imager collects a low-resolution image. The final high-resolution image is reconstructed from these low-resolution images, using a sophisticated image reconstruction algorithm. To arrive at the effective MTF of the sensor, the effect of this reconstruction algorithm on the MTF needs to be analyzed. We propose to determine the effective MTF of a hypothetical single aperture system that provides a resultant image equal in Mean Square Error to that of the reconstruction algorithm, using the LMMSE algorithm. The effective MTF was analyzed for the following scenarios: sub-imagers with identical MTF's and sub-imagers with different MTF's. It has been shown in [6, 7] that diversity in MTF's greatly improves the performance of the reconstruction algorithm. In the first case, no performance gain in terms of MTF results, by combining data from the sub-imagers. However, the effective noise is reduced. In the second case, under mild constraints, the effective MTF is the RMS value of the sub-imager MTF's.

3. References

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