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High-speed, High-accuracy Direct General Transfer Function Estimation Using a new Well-Optimized Linear Finder (WOLF) Method with Application to Diversity-based Atmospheric Turbulence Compensated Imaging Systems

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KEYNOTE SPEAKER

A new high-speed, high-accuracy general transfer function estimation method is presented that has been found to be faster and more accurate than traditional methods used in transfer function estimation/blind-deconvolution problems such as removing atmospheric turbulence from coherent and incoherent optical imagery. Our new Well-Optimized Linear Finder (WOLF) method applies across the electromagnetic and acoustic spectrum and benefits any linear/linear shift-invariant (or linearizable) system where channel aberrations can be well-modeled as phase aberrations. A representative example of these type of aberrations are atmospheric aberrations found in imaging systems that are dominated by near-field atmospheric turbulence such as ground-to-air, or ground-to-space imaging systems. Our correlation-based method is implemented entirely in the spatial frequency domain and takes advantage of transfer function phase redundancies in the transfer function's complex exponential entrance pupil plane phase difference chains. In traditional methods, for imaging systems with a large number of pixels (or equivalently a large number of entrance pupil plane samples), up to millions of complex exponential phase differences need to be determined and summed at discrete points of the Optical Transfer Function (OTF). In our WOLF method, these millions of complex exponential phase difference sums have been reduced to a requirement of no more than the sum of 3 complex exponential phase difference terms at any point of the OTF. Additionally, unlike many traditional blind deconvolution methods that use iterative, weighted basis function expansion methods to estimate entrance pupil plane phase aberrations, our WOLF method is a single iteration method capable of exactly reproducing the entrance pupil plane phase given adequate entrance pupil plane sampling. Also, due to symmetries and the inherent phase redundancies in the OTF, only a subset of the OTF points need to be evaluated to fully determine the entrance pupil plane phase aberrations, further reducing the computational requirements of the WOLF method. As an example, we demonstrate the WOLF method on a simulated diversity-based imaging system using a statistically accurate realization of the Earth's atmosphere based on the Kolmogorov atmospheric model. We apply the atmospheric aberrations to a pair of 256 by 256 images (image and diversity image) and show that on a 2014 MacBook Pro computer with a 2.8 GHz Quad-Core Intel Core i7 processor with 16 GB of 1600 MHz DDR3 memory and running Matlab 2020b, the nonoptimized, non-parallel implementation of the WOLF method can reconstruct the turbulence free, diffraction-limited image in approximately 8 seconds. Our WOLF method is implementable using parallel processing technologies such as the Graphical Processing Unit (GPU) on a conventional laptop computer and/or Field Programmable Gated Array technologies with expected real-time (faster than 30 Hz) performance for software-dominant transfer function estimation/blind deconvolution/atmospheric turbulence compensation problems. The effects of additive Gaussian noise on the WOLF method are also presented.

KeyWords: General Transfer Function Estimation, Adaptive Optics, Atmospheric Turbulence Compensation, Blind Deconvolution Methods.

Biography

Dr. Arrasmith is currently a professor in the Department of Engineering Systems at FIT. He has 20 years experience with government research and development programs and has had extensive exposure to electro-optical, infrared, and laser detection systems. Prior to his position at Florida Tech, Dr. Arrasmith served as Program Manager of Physics and Electronics at the Air Force Office of Scientific Research (AFOSR) in Washington DC. In 1997 he moved to the United States Naval Academy in Annapolis, Maryland to teach courses in Engineering and Linear Adaptive Optics. Dr. Arrasmith was then reassigned to the Air Force Technical Applications Center (AFTAC) at Patrick Air Force Base where he became Chief of the Systems and Technology Division. He was later appointed Division Chief for the Advanced Science and Technology Division of the AFTAC and remained in the position until joining Florida Tech in 2003.