SIGNAL PROCESSING USING THE SELF-DECONVOLVING DATA RECONSTRUCTION ALGORITHM

GOVERNMENT INTERESTS

This invention was partly developed with U.S. Government support while performing research at the Naval Research Laboratory in Washington, D.C. The U.S. Government may have certain rights to this invention.

CROSS-REFERENCE TO RELATED APPLICATIONS

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FIELD OF INVENTION

This invention relates to methods of signal processing whereby one desires to restore a signal that exhibits degradation, specifically to a process that identifies the degradation, providing the opportunity to restore the signal using a deconvolution algorithm.

SUMMARY OF THE INVENTION

A blind deconvolution process has been developed that requires no information about the degradation and little computation. The technique extracts a filter function from a signal or data set by application of a power law to the Fourier transform of the signal. The filter function is cleaned and inserted into a standard deconvolution process, potentially removing the aberration from the signal.

This process has several advantages over existing blind deconvolution techniques. The process is computationally efficient, requires only one iteration, and contains one significant parameter. The process is quick. The entire operation takes a few seconds to process a data set on a standard personal computer and could potentially process sound information in near real-time. The computer code is relatively simple, allowing easy implementation into existing signal and image processing programs. Most importantly, the results usually cannot be discerned from a restored signal where the degradation was known.

This process has many potential commercial applications. As will be shown here, degradations such as optics or motion blur, can be removed from digital (or digitized) images. Image processing programs can employ the algorithm alongside more common edge sharpening and median filters. Digitizing scanners can use it to counteract blurring effects created by their optics. The process can be embedded into digital oscilloscopes and data analyzers to bring out higher frequency components that are suppressed by certain low-pass filtering processes.

This process may also be embedded into circuitry. Communication lines may suffer from attenuation over long distances. By restoring degraded signals, the length of transmission may be extended. And as processors become smaller, they may find their way into household devices such as stereo systems and hearing aids. The algorithm could be implemented in these devices to enhance performance.

The novelty of this process is the Self-Deconvolving Data Reconstruction Algorithm (SeDDaRA). In SeDDaRA, a filter function is extracted from a degraded signal. A filter function is extracted from the data set that can be used to identify degradation and restore the signal. This document will describe SeDDaRA and the data restoration process. Since this method was developed as an image processing

tool, application to two-dimensional data will be discussed in greater detail. However, the theory and application of this technique is equally as valid for one-dimensional data. This document will provide background, the known theory, current developments, alternative approaches, and the blind deconvolution process. Diverse examples will demonstrate the application and effectiveness of the procedure. Finally, a list of potential applications will be presented.

BACKGROUND

Prior Art

Signal reconstruction based on deconvolution has been thoroughly studied in recent decades. Some references for image reconstruction of note are listed in the references. [1, 2, 3] Some standard methods will be discussed in the following section. Blind deconvolutions are significantly more rare, although a sizable amount of research has been conducted recently. [4, 5, 6, 7, 8]

Several patents have been issued over the last decades that cover signal restoration processes. Generally, these methods are similar in that they attempt to identify the system degradation, and use a deconvolution algorithm to restore the signal as best as possible. The methods that have broad application include a blind deconvolution technique using maximum entropy, (Torkkola, U.S. Pat. No. 5,959,966, 1999) an iterative method for digital image restoration based on partial differential equations, (Carasso, U.S. Pat. No. 5,414,782, 1995) an iterative image restoration device based on noise minimization, (Carrington, U.S. Pat. No. 5,047, 968, 1991) a noise filtering method using a Wiener variant filter, (Wober, U.S. Pat. No. 5,729,631, 1998) an apparatus for imaging and signal processing that establishes a figure of merit, (McCarthy, U.S. Pat. No. 6,014,468, 2000) and a method for restoring multiple frames using a Wiener filter. (Erdem, U.S. Pat. No. 5,550,935, 1996) Other methods have narrowly-defined applications. These include a method for blind restoration of radio signals, (Torkkola, U.S. Pat. No. 5,959,966, 1999) a method for removing blurs stemming from air turbulence in telescopes, (G. B. Rhoads, U.S. Pat. No. 6,084,227, 2000) a method that determines the impulse response from an interferometer, (Kulka-rni, et. al., U.S. Pat. No. 5,994,690, 1999) a method for removing noise from a video signal using a Wiener filter, (Kokaram, U.S. Pat. No. 5,500,685, 1996) a system for automatic processing of images using an interferometer system, (Kulkarni, U.S. Pat. No. 5,694,484, Dec.02, 1997) a method for the restoration of images disturbed by atmospheric conditions, (Kopeika, U.S. Pat. No. 5,841,911, 1998) and a method for the restoration of images degraded by mechanical vibrations (Kopeika, U.S. Pat. No. 5,790,709, 1998).

The process proposed here is distinct from these methods in its approach and simplicity. Many restoration algorithms require much computation and user intervention. SeDDaRA can be accomplished with a few lines of computer code, one iteration, and limited user input. Most processes above are limited in application and may not function well in the presence of noise. As will be shown, SeDDaRA can be applied in many situations and succeeds in the presence of noise.

Deconvolution Theory

The objective of data restoration, also referred to as reconstruction, is to remove a degradation from data that, with an ideal detection system, would not be there. If the form of the degradation is known, then a class of standard