Chapter 21
Image and Video Restoration and Enhancement via Sparse Representation

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ABSTRACT

The chapter provides a survey of recent advances in image/video restoration and enhancement via spare representation. Images/videos usually unavoidably suffer from noises due to sensor imperfection or poor illumination. Numerous contributions have addressed this problem from diverse points of view. Recently, the use of sparse and redundant representations over learned dictionaries has become one specific approach. One goal here is to provide a survey of advances in image/video denoising via sparse representation. Moreover, to consider more general types of noise, this chapter also addresses the problems about removals of structured/unstructured components (e.g., rain streaks or blocking artifacts) from image/video. Moreover, image/video quality may be degraded from low-resolution due to low-cost acquisition. Hence, this chapter also provides a survey of recently advances in super-resolution via sparse representation. Finally, the conclusion can be drawn that sparse representation techniques have been reliable solutions in several problems of image/video restoration and enhancement.

INTRODUCTION

With the rapid development of multimedia and network technologies, displaying and delivering digital multimedia contents (e.g., image/video data) through the Internet and heterogeneous devices has become more and more popular. However, digital images/videos usually unavoidably suffer from noises, which may arise from sensor imperfection, poor illumination, or communication errors (Buades, Coll, & Morel, 2005; Elad, 2010; Ohta, 2007). Image/video noise is usually random variation of brightness

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or color information in digital images/videos. For example, a typical model of image noise is Gaussian and additive, which is independent at each pixel, and independent of the signal intensity. The principal sources of Gaussian noise in digital images/videos arise during acquisition, e.g., sensor noise, caused by poor illumination, high temperature, or transmission (Nakamura, 2005; Boncelet, 2005).

In addition, to consider more types of image noise, digital images/videos may usually also suffer from bad weather effects, such as, rain streaks (Garg & Nayar, 2007; Bossu, Hautière, & Tarel, 2011; Shehata et al., 2008), snow (Bossu, Hautière, & Tarel, 2011), or haze (or fog) (He, Sun, & Tang, 2011; Yeh, Kang, Lee, & Lin, 2013) (e.g., outdoor surveillance video), compression artifacts (for storage and transmission) (Shen & Kuo, 1998; List, Joch, Lainema, Bjontegaard, & Karczewicz, 2003; Yeh, Ku, Fan Jiang, Chen, & Jhu, 2012), or other undesired components (e.g., induced by image synthesis, manipulation, or editing) (Parra & Sajda, 2003; Haykin & Chen, 2005). On the other hand, besides noises, image/video quality may be also degraded from low-resolution (LR) due to low-cost acquisition system (Park, Park, & Kang, 2003; Farsiu, Robinson, Elad, & Milanfar, 2004; Freeman, Jones, & Pasztor, 2002, Freedman & Fattal, 2011).

To achieve image/video restoration and enhancement, several approaches, such as denoising (Shao, Yan, Li, & Liu, 2014; Buades, Coll, & Morel, 2005), removal of blocking artifacts (deblocking) (Shen & Kuo, 1998; List, Joch, Lainema, Bjontegaard, & Karczewicz, 2003; Yeh, Ku, Fan Jiang, Chen, & Jhu, 2012), removal of rain streaks (deraining) (Garg & Nayar, 2007; Bossu, Hautière, & Tarel, 2011; Shehata et al., 2008), removal of undesired components (Parra & Sajda, 2003; Haykin & Chen, 2005), and enhancement of resolution (Park, Park, & Kang, 2003; Farsiu, Robinson, Elad, & Milanfar, 2004; Freeman, Jones, & Pasztor, 2002, Freedman & Fattal, 2011) for image/video have been proposed. Several of them have been shown to lead to good results.

In recent years, sparse representation techniques (Dong, Shi, Ma, & Li, 2015; Starck, Fadili, Elad, Nowak, & Tsakalides, 2011; Baraniuk, Candès, Elad, & Ma, 2010; Elad, Figueiredo, & Ma, 2010; Elad, 2010; Olshausen & Field, 1996; Bruckstein, Donoho, & Elad, 2009) have been popular in these applications and have been shown to achieve state-of-the-art performances. Sparse representation, also known as sparse coding (Elad, 2010; Olshausen & Field, 1996; Bruckstein, Donoho, & Elad, 2009), is a technique of finding a sparse representation for a signal with a small number of nonzero or significant coefficients corresponding to the atoms in a dictionary (Giryes & Elad, 2014; Rubinstein, Peleg, & Elad, 2013; Elad, 2012; Rubinstein, Bruckstein, & Elad, 2010; Mairal, Bach, Ponce, & Sapiro, 2010; Aharon, Elad, & Bruckstein, 2006). It has been successfully applied to different types of signal decomposition applications (Fadili, Starck, Bobin, & Moudden, 2010; Kang, Yeh, Chen, & Lin, 2014). For examples, image/video denoising or restoration (Elad & Aharon, 2006; Mairal, Elad, & Sapiro, 2008; Mairal, Bach, & Ponce, 2012; Guo, Qu, Du, Wu, & Chen, 2014; Sun, Gao, Lu, Huang, & Li, 2014; Zhang, Zhao, & Gao, 2014; He, Wang, Zhang, Xu, & Lu, 2015; Liu, Zhang, Guo, Xu, & Zhou, 2015), deraining (Kang, Yeh, Chen, & Lin, 2014, Kang, Lin, & Fu, 2012; Kang, Lin, Lin, & Lin, 2012; Huang, Kang, Yang, Lin, & Wang, 2012; Huang, Kang, Wang, & Lin, 2014; Chen, Chen, & Kang, 2014; Chen & Hsu, 2013), deblocking (Jung, Jiao, Qi, & Sun, 2012; Yeh, Kang, Chiou, Lin, & Fan Jiang, 2014), removal of other components (Fadili, Starck, Bobin, & Moudden, 2010; Bobin, Starck, Fadili, Moudden, & Donoho, 2007; Starck, Elad, & Donoho, 2005), image/video super-resolution (Yang, Wright, Huang, & Ma, 2010; Yang, Wang, Lin, Cohen, & Huang, 2012; Dong, Zhang, Shi, & Wu, 2011; Ren, Liu, & Guo, 2013; Yang, Huang, & Yang, 2010; Yang & Wang, 2013; Tsai, Huang, Yang, Kang, & Wang, 2012; Kang, Chuang, Hsu, Lin, & Yeh, 2013; Peleg & Elad, 2014; Romano, Protter, & Elad, 2014; Zhang, Liu, Yang, & Guo, 2015; Kang, Hsu, Zhuang, Lin, & Yeh, 2015), and image/video recognition, classification, or understanding

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