Quasi noise-free digital holography

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Noise originating from the coherent nature of laser light is the scourge of digital holography, reducing the quality of holographic images below that of conventional photographs. Now, Pasquale Memmolo of ISASI-CNR and collaborators have practically eliminated such noise by using a two-stage algorithm that exhibited both qualitative and quantitative improvement over recently developed de-noising techniques. In particular, the algorithm reduced noise in background regions by 98 percent and in signal regions by 92 percent.

Digital holography is a powerful imaging technique for 3-D vision and display systems. However, the use of coherent light sources introduces annoying visual phenomena, namely speckle noise, an intrinsic interference effect due to the laser. Such coherent noise severely degrades the corresponding reconstruction quality in holographic systems. The reduction of the light coherence, by engineering the laser source or by recording and combining multiple holograms, were the two main techniques to address this problem. In particular, multi-look digital holography (MLDH) is one of the most efficient techniques to improve the quality of both the numerical and optical reconstructions. Nevertheless, several methods have been proposed to reduce holograms noise by implementing sophisticated processes, which are typically applied on numerical reconstructions of digital holograms for image visualization enhancement. Very few methods for working directly on recorded holograms to improve quality have been developed.

Among these methods, 3-D block matching filtering (BM3D) has demonstrated very powerful denoising capabilities in the field of digital

image processing, by means of a block grouping and collaborative filtering strategy. However, this method requires a certain level of the initial signal-to-noise ratio (SNR) of images to be processed; otherwise, an incorrect grouping could occur, cutting down the reconstruction quality. To overcome this limitation, preliminary filtering is typically employed in the case of images with low SNR, as in the case of digital holograms.

The researchers implemented a joint action of MLDH, grouping and collaborative filtering. The technique achieves high-quality numerical reconstructions in digital holography. They refer to this proposed method as MLDH-BM3D. In particular, MLDH pre-processing achieves the enhanced grouping step, ensuring better working conditions for the iterative processing blocks of the collaborative sparse 3-D filtering. They demonstrated that MLDH and BM3D can be considered as complementary steps, mixing smart optical recording methods and numerical processing. The approach works efficiently for digital holography of both single and multiple wavelengths, achieving noise suppression of up to 98 percent, thus demonstrating very high quality holographic 3-D reconstructions that can be considered a "noise-free" for human vision.

This impressive result can pave the way to the next generation of holographic imaging systems based on laser technology.

More information: Vittorio Bianco et al, Quasi noise-free digital holography, *Light: Science & Applications* (2016). DOI: 10.1038/lsa.2016.142

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