Evaluation of the compressibility of Computer-Generated Holograms

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We present a preliminary investigation of the compressibility of Physically-Based Computer-Generated Holograms (PB CGHs) as represented in various bases. The goal is to identify which bases, if any, are suitable for applying the principles of Compressed Sensing (CS) to the generation of PB CGHs.

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Motivation

Physically-Based Computer-Generated Holography (PB CGH), although capable of emulating realistic 3D perception, involves extremely high sampling rates and computationally taxing generation algorithms, which make its use impractical. A possible path to overcome these issues is using **Compressed Sensing** (CS) [RSJ10], which provides a way to reduce the sampling rates below the Nyquist frequency limit without loss of information, as long as the signal is captured in a basis where its representation is sparse (i.e. has many zero or near-zero coefficients) [HR09].

Methodology

Despite many studies resorting to established [HR09] or novel [OOAF09] sparsity measures, in the case of holography, since it is an intermediate representation of the final images, in addition to identifying the bases where PB CGHs are sparse, we must ensure that they also minimize reconstruction error in the final images.

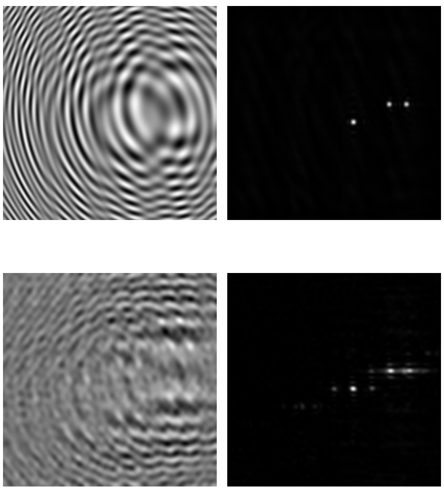

Figure 1. A sample of the data generated for this study. Shown is the simplest "object" used, with only 3 points. The top row depicts the original hologram and its digital reconstruction as an image, while the bottom row shows the same hologram after having 99.5% of its coefficients removed (the highest of the compression levels used) in the DFT basis and its reconstruction.

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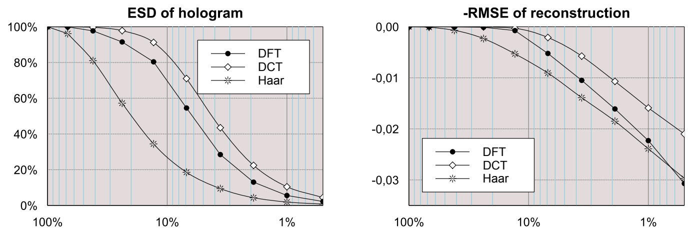

Figure 2. Plots of the obtained values for the Energy Spectral Density of the holograms and the reverse Root-Mean-Square Error of the images (in both cases, higher is better). Each data point is the averaged score for the 15 objects tested.

A two-step empirical approach has been employed: first, PB holograms were generated from 15 point-cloud 3D models, with sizes ranging from 3 to 42 744 points. These holograms were converted to three distinct representation bases (DFT, DCT and Haar wavelets), had coefficients in those bases progressively removed, and were converted back to the canonical domain. This allowed comparing the pure information preservation properties of each basis as encoders for holographic data, using several metrics, such as the Energy Spectral Density shown on Fig. 2 a).

The second step was reconstructing reference images for each of these compressed holograms and comparing them to the uncompressed reconstructions, using absolute error (RMSE), signal-to-noise ratio, and the image-specific SSIM. The RMSE plot (averaged for all holograms tested) is shown in Fig. 2 b).

Results & Conclusions

Although the literature favored Haar wavelets for (non-PB) CGHs [RSR11], **the results obtained demonstrate that the DCT is the basis with the best performance in the evaluated metrics**. This establishes a compelling case for further research into applying CS to PB CGHs with DCT as a basis.

References

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