Imaging incoherent target using Hadamard basis patterns

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Abstract

In this paper, we present a correlation-based imaging technique in single pixel imaging scheme using Hadamard basis illumination. The Hadamard basis, which has the characteristics of a two-bit value (−1, +1) and sparsity in its transformed domain, has been used in the illumination patterns and successfully utilized for imaging an incoherent target. Simulation results of imaging with both Hadamrd pattern and Fourier pattern are shown.

Introduction

- Correlation based imaging technique is an unconventional approach where an object is reconstructed as the distribution of correlations of the light field
- We present a single pixel correlation imaging using Hadamard and cosine basis
- In single pixel imaging, object is illuminated with structured light patterns and corresponding to each light pattern single pixel detector records light signal
- Single pixel detector can operate at other wavelength regions even in low light condition
- The Hadamard basis are binary patterns, suitable for computational imaging
- Such deterministic patterns reduce the number of measurements and acquisition time
- Simulation results for both Hadamard basis and Cosine basis are presented and compared

Theory

In the HSI scheme, the Hadamard transform (H{ }) of an object A(x, y) is expressed as

$$\boldsymbol{H\{A(x,y)\}} = \sum_{x=0}^{L-1}\sum_{y=0}^{L-1} \boldsymbol{A(x,y)(-1)^{w(x,y,u,v)}}$$

Where $w(x,y,u,v) = \sum_{i=0}^{n-1} [g_i(u)x_i + g_i(v)y_i]$

And $g_{n-1}(u) = u_1 + u_o$

Hadamard basis pattern $P_H(x, y)$

$$\boldsymbol{P_H(x,y)} = \frac{\mathbf{1}}{\mathbf{2}}[\mathbf{1} + \boldsymbol{H^{-1}\{\delta_H(u,v)\}}]$$

Where $\boldsymbol{\delta_H(u,v)} = \begin{cases} \mathbf{1}, \boldsymbol{if\ u = u_0\ and\ v = v_0} \\ \mathbf{0}, \boldsymbol{otherwise} \end{cases}$

H^{-1} → inverse Hadamard transform and $\delta_H(u,v)$ → delta function.

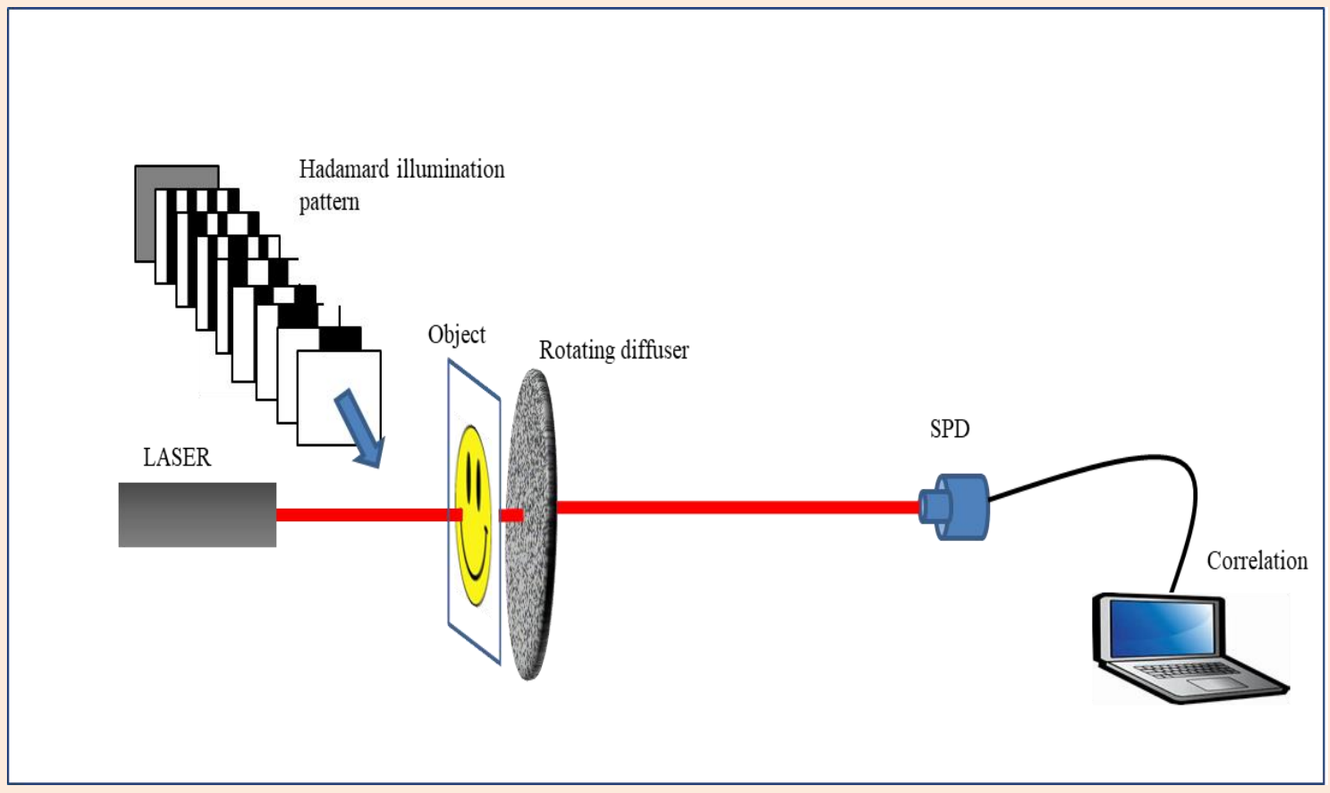
→ Object is obscured by a dynamic diffuser

→ SPD measures → D_+ corresponding to P_H, D_- corresponding to $1\text{-}P_H$.

Hadamard coefficient → $\boldsymbol{H(u,v) = D_+ - D_-}$

$\boldsymbol{H(u,v)}$ → Inverse Hadamard transform → Object reconstruction

Schematic diagram of proposed set up



Results and Discussion

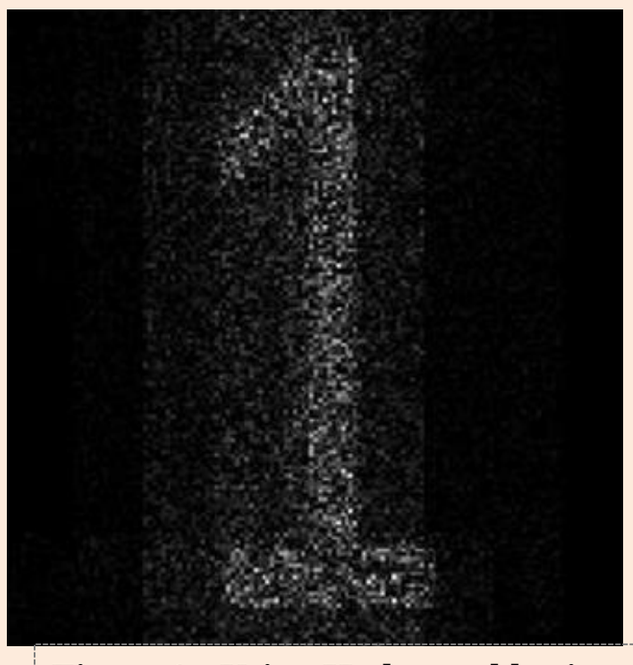


Figure 1: Using Hadamard basis

Figure 2: Using cosine basis

Conclusion

- Deterministic Hadamard pattern helps in single pixel imaging scheme by solving the problem of a huge number of measurements
- We have successfully used Hadamard basis illumination to image an incoherent target hidden behind the diffuser
- Differential measurement of Hadamard coefficient reduces noise and is easier than phase shifting in case of Fourier basis pattern
- Further to compare reconstruction quality we have also shown simulation result using Fourier basis pattern

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