Passive Non-line-of-sight Source Classification from Coherence Measurements

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Abstract: We demonstrate a passive imaging approach for identifying the shape and size of a secondary source using non-line-of-sight spatial coherence measurements.

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1. Introduction

Some existing approaches for non-line-of-sight measurements require *active* control of the scene either by modifying the incident field [1], or by using an active laser source and measuring time-of-flight information [2]. Here, we demonstrate an algorithm to detect the hidden object using only *passive* coherence measurements.

2. Model

The spatial coherence function is defined as $\Gamma(\mathbf{r},\mathbf{s}) = \langle E(\mathbf{r}+\frac{\mathbf{s}}{2})E^*(\mathbf{r}-\frac{\mathbf{s}}{2})\rangle$. The forward propagation model consists of a Gaussian source $\Gamma_s(x,y,s_x,s_y) = I_{in}(x,y;\theta)\exp\left(-\frac{s_x^2}{2\sigma^2}\right)\exp\left(-\frac{s_y^2}{2\sigma^2}\right)$, where θ is a vector of source parameters. Free space Fresnel propagation, e.g., in [3], is used to obtain the coherence $\Gamma_i(x,y,s_x,s_y)$ incident upon the scattering surface. The indirect propagation affects the coherence properties. This effect can be considered as a Gaussian transfer function for the coherence function corresponding to the incident field [4].

Given a measured coherence function Γ_m, the inversion is accomplished by minimizing the residual $\|\Gamma_r(\theta)-\Gamma_m\|_2^2$ with respect to θ where $\Gamma_r(\theta)$ is the theoretical reflected coherence for the given source parameters. A Levenberg-Marquardt least squares fitting algorithm is used to perform the minimization. Measurements of coherence along one direction suffices. Upon reflection at grazing angles, the coherence is better preserved in the off-plane direction (y-axis) than in the in-plane direction (x-axis) [4]. This motivates our choice of using coherence data only along the y-axis.

3. Results

The first problem seeks to estimate the size of a source given its shape. The example here considers a square shaped source, where we seek to estimate its width. Simulated measurements were obtained by means of forward propagation followed by scattering using Monte Carlo simulations; both operations have been previously found to match experimental results, [3, 5]. As can be seen in Fig. 1 (a), the estimation of the width was successful with convergence after six iterations.

Extending the estimating results, we are able to solve the shape classification problem by using the first zero crossing. The same measurements Γ_m are used as in the previous example, but the new goal is to also classify the shape as either a square or a circle. The minimization problem also allows for a circular source of a specific width to produce the same reflected coherence as the square, see Fig. 1(b). The correct shape is discriminated by using the zero crossing along one axis, as shown in Fig. 1(c). This allows the shape to be successfully classified.

4. Conclusion

A technique was presented to estimate size and classify a non-line-of-sight secondary source. Of particular note, this technique uses only coherence measurements, and does not require active control of the sources or scene.

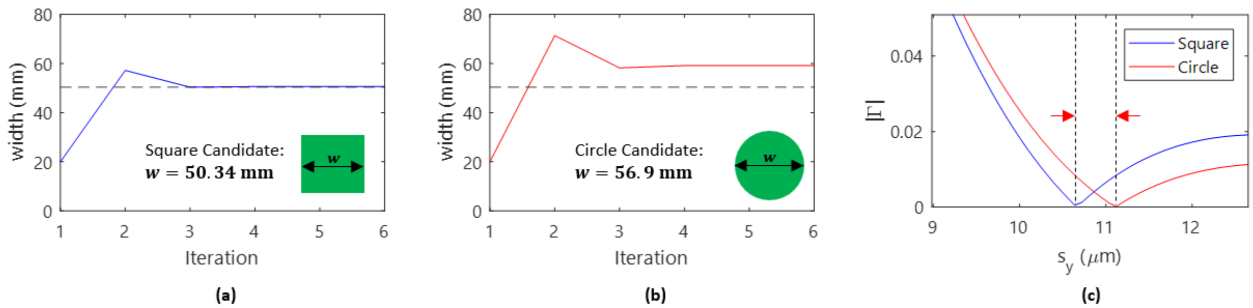

Fig. 1. (a) Estimation of square width w. (b) Estimation of circle diameter w using same measurements as in (a). (c) Comparison of zero crossings of square and circle coherence functions.

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