COMPUTATIONAL AGILE BEAM LADAR IMAGING

Arthita Ghosh[1], Vishal M. Patel[2], Michael A. Powers[3]

1. Department of Electrical and Computer Engineering, University of Maryland, College Park, MD 20742, USA
2. Department of Electrical and Computer Engineering Rutgers, The State University of New Jersey, Piscataway, NJ 08854, USA
3. General Dynamics, 1231 Tech Court, Westminster, MD 21157

Motivation/Introduction

- The LAser Detection And Ranging (LADAR) apparatus obtains range information from a 3D scene by emitting laser beams.
- The Agile Beam LADAR concept introduces computational approach in measurement and interpretation stages.
- **We show that effective object recognition is possible in the measurement domain thereby eliminating the necessity for reconstruction**

Measurement Apparatus Overview

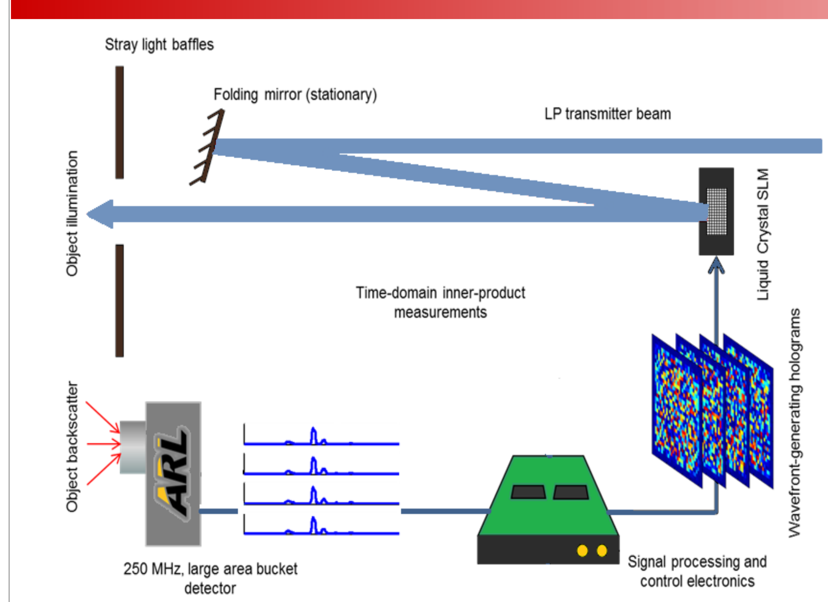

Fig. 1: Block diagram of a prototype Agile beam LADAR architecture.

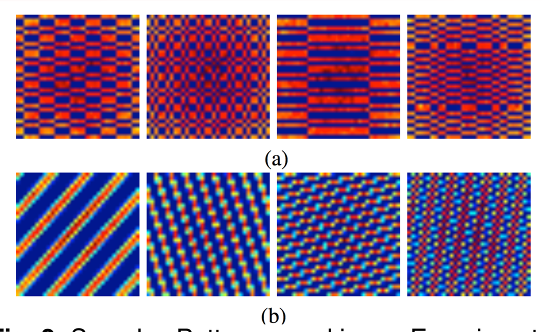

Fig. 2: Samples Patterns used in our Experimental Prototype. (a)Hadamard. (b) DCT.

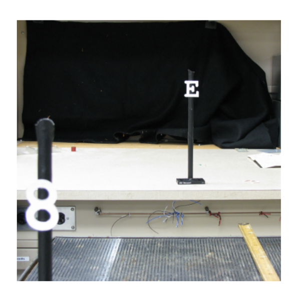

Fig. 3: Objects used for collecting data

- A linearly-polarized transmitter beam at 1550 nm, is generated by a 2-ns pulsed fiber laser and collimated using a multi-element lens. A distant target is about 3 meters away from the aperture. The receiver feeds a high speed digitizer.
- A series of pulsed far-field illumination patterns are generated, whose time properties are defined by a laser pulse & cross-range spatial properties of laser beam controlled by a computer-generated hologram written to the SLM

LADAR Data

- System generates voxels in a 32x32x301 data cube
- 3 measurement modes - 1024 digital holograms whose far field illumination patterns are rows of the (1)Identity(raster Scanning) (2) DCT (3) Hadamard matrices
- Peaks in the timing histograms were used to identify slices where the objects are present
- Inverting the measurement matrix transforms the measurements to pixel basis

Image Recovery

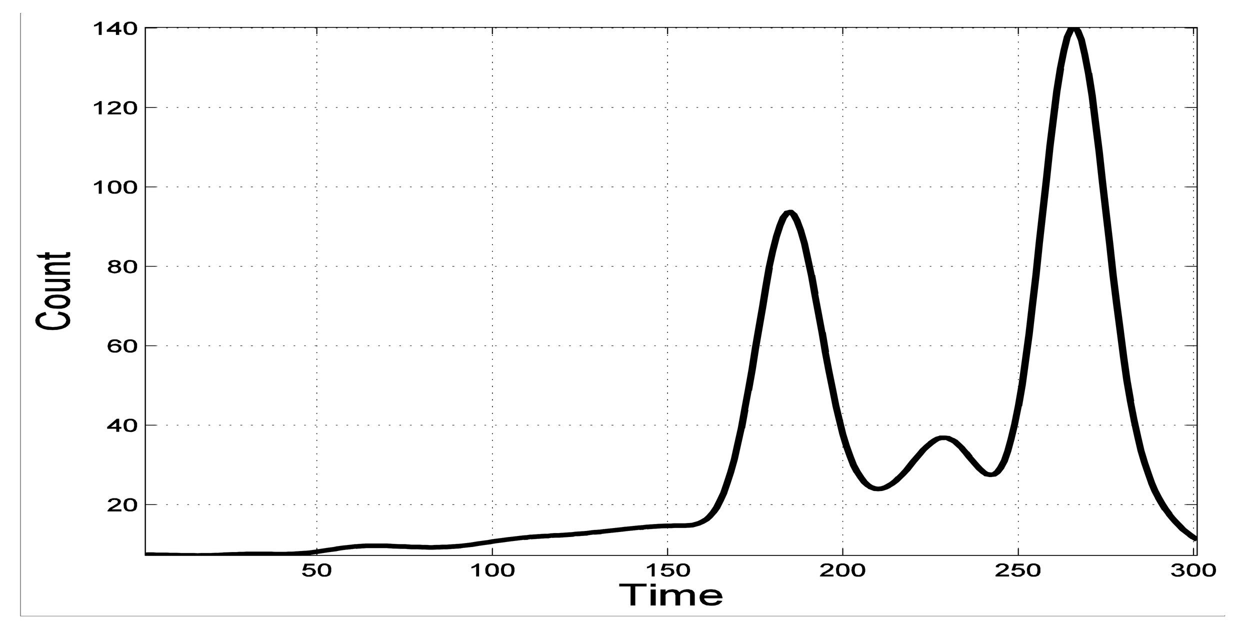

Fig. 4: Timing Histogram. Peaks corresponding to slices where objects are present. Largest peak is due to the reflection from the background

- Ladar Process: y = **A**x + b
- Recovering x by direct inversion leads to noisy outputs [4]
- $l1$ - minimization :

$$\hat{x} = \arg\min_{x} \lambda ||x||_1 + \frac{1}{2}||y - Ax||_2^2$$

- Reconstruction can be slow and output quality may depend on measurement mode

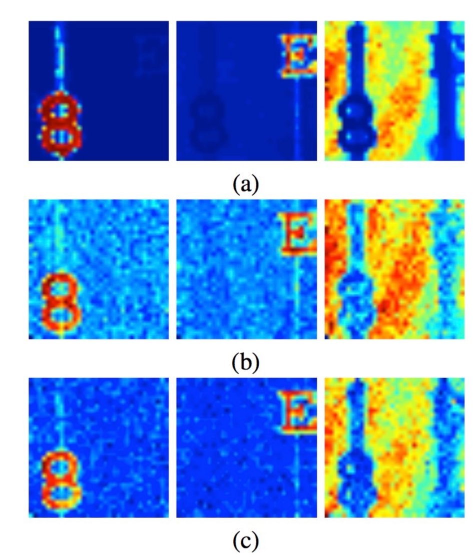

Fig. 5: Measured data. From left to right: reconstructed foreground object "8", reconstructed background object "E" and background clutter. (a) Raster scan. (b) Hadamard. (c) DCT.

Measurement Domain Object Recognition

- LADAR measurements were simulated using the measured point spread functions corresponding to 3 different modes from our agile beam LADAR prototype.
- Average performance achieved in Measurement Domain was compared with that attained in the original binary image domain using the same classifiers.
- Performance in the raster scan mode(comparable to classic techniques) was found to be uniformly dominated by the performances in the Hadamard and DCT domains.
- Recognition rates achieved by inverting the transformation to visual domain were similar to those in the measurement domain thereby showing no significant gain in inversion.
- Avoiding the inversion led to reduction in computational effort.

Experiments

- **Binary Alpha Digits dataset:** contains 39 binary images(20x16) per class and 36 classes. We show the results only on the digits.
- We varied the number of training samples between 10 and 25 and tested on the rest
- In order to simulate the measurements, we first resized the digits to 32x32 and then convolved the digits with the measured psfs.
- **Classifiers used for comparison:** Nearest Neighbor(NN), Nearest Subspace(NS) and Linear Multiclass Support Vector Machine(SVM)

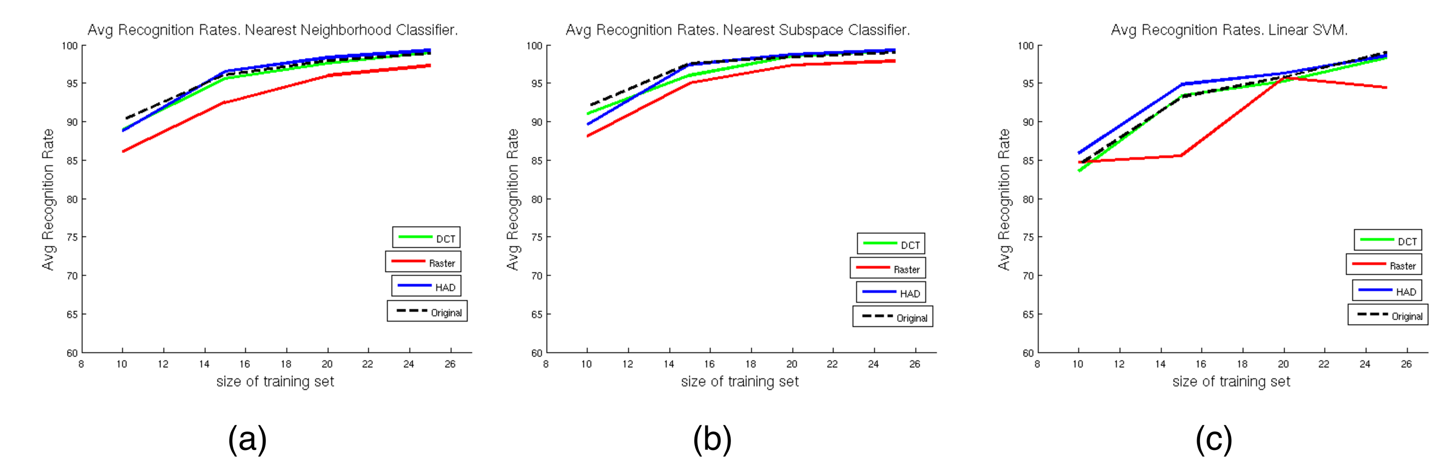

Fig. 6. Recognition accuracy vs. training set size for NN(a), NS(b) and SVM(c) classifiers

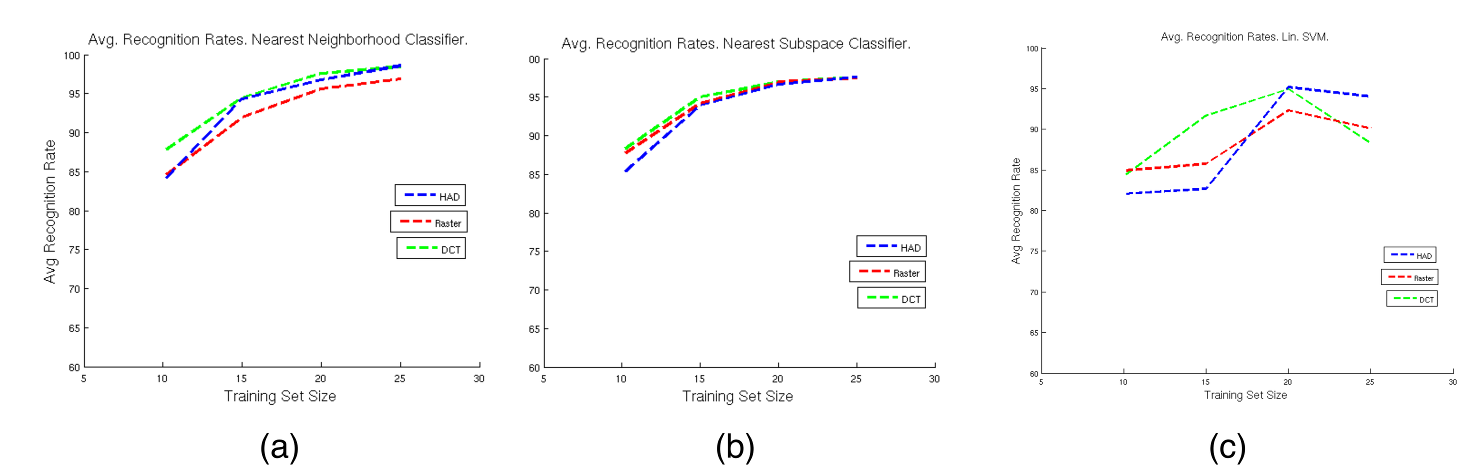

Fig. 7. Recognition accuracy following image recovery via sensing matrix inversion for NN(a), NS(b) and SVM(c) classifiers

References

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