Evaluation of the Impacts of Compressive Sensing Imaging Processing Parameters

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Background

- Unmanned aerial vehicles and autonomous underwater vehicles have a critical need for a compact and low power imaging system that can acquire high-fidelity imagery in degraded visual environments, such as haze, fog and turbid water.
- The existing laser line sensing technique is large and consumes a significant amount of power while performing serial raster scans to acquire raw data.
- The compressive sensing theory enables the reconstruction of the original signal using incomplete incoherent linear measurements by taking advantage of the fact that a natural scene in general contains highly correlated information.
- The availability of the Texas Instruments digital micromirror device (DMD) made it possible to project the 1D patterns generated randomly on the target.
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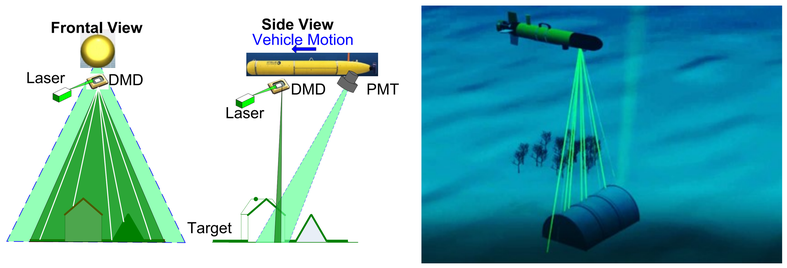
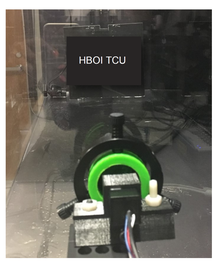


Figure 1. An autonomous underwater vehicle is acquiring data from the target.

The Data Acquisition System

The key components of the compressive sensing based prototype include

(1) an illumination subsystem that includes a laser, a DMD, and illumination optic;
(2) a signal detection subsystem that includes a photomultiplier tube (PMT);
(3) a data acquisition board and a computer.;
(4) A target with black background controlled by a linear glider.



Target in water tank

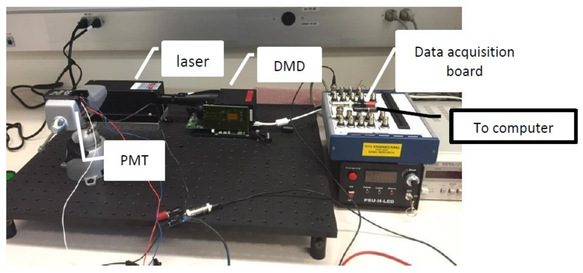


Figure 2. The compressive sensing based imaging system set up

Experiment Results

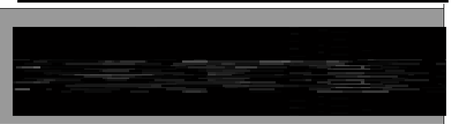
Compression Ratio	Line Group	Image
1/2	1	
1/2	5	
1/4	1	
1/4	5	
1/8	1	
1/8	5	

Figure 3. Reconstructed images using different compression ratios and line groups.

The above images were processed using six different combinations of compression ratios and line groups. From looking at the images above, it is clear that the image quality is greatly decreased as the compression ratio increases. This is because the larger compression ratios use less data to reconstruct the original image. Increasing the line group from 1 to 5 helps to restore some of the image resolution because the higher line group uses data from more lines above and below the line of interest. The impact of increasing the line group can be most clearly seen with the 1/8 compression ratio. When using a compression ratio of 1/8 with 1 line group, the image is not at all recognizable, and all you can see are a few white streaks. When increasing the line group to 5 for the same compression ratio, there is a distinct improvement in the image resolution. While it is still not good, you can make out a few of the letters in the image.

System Operation

- The laser light source will be directed at a Digital Micromirror Device (DMD)-based projector.
- The DMD-based project will be project the binary patterns onto the target.
- A Z-axis glider will be used to direct the target up and down to ease the process of collecting data.
- A PMT will then collect the reflected light photons from the target.
- The data acquisition board will receive the data collected by the PMT and transfer the data to the computer.
- A MATLAB based computer software will process the data and reconstruct the target image.
- This process will be run in various environments such as air, clear water and turbid water. We will use an aquarium tank to test the system in different turbidities of water.

Future Work

The future work of this project will consist of determining the binary patterns that will result in the better image quality at different media such as air, clear water and turbid water. Sparse binary patterns are likely to produce better image quality in scattering media such as turbid water based on the theory and we will verify it through experiments. We will continue to evaluate the tradeoff between compression ratio and number of lines to be used for the imaging reconstruction process.