Invited Paper

Data Dome: Full k-Space sampling data for high frequency radar research

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ABSTRACT

Visual-D is a 2004 DARPA/IXO seedling effort that would develop a capability for reliable high confidence ID from standoff ranges. Being able to form optical-quality SAR images (exploiting full polarization, wide angle, etc) would key evidence that such a capability is achievable. The seedling team produced a public release data set and associated challenge problems to support community research in this area. The premise of this paper is to describe the full data set and 3 associated challenge problems that are defined over interesting subsets of the full data set.

Keywords: Visual-D, challenge problems, optical-quality SAR images

1. INTRODUCTION

The full public release data set is referred to as the "Backhoe Data Dome, Version 1.0". It consists of simulated wideband, full polarization, complex backscatter data from a backhoe vehicle in free space. The backscatter data was generated over a full upper 2π steradian viewing hemisphere and occupies approximately 90 GB of disk space. For the first challenge, "Problem 1: Sparse Aperture and 3D Images" k-space data for a window of 48° in azimuth and 24° in elevation centered at 90° in azimuth and 30° in elevation is given as well as a randomly generated path within a box that simulates a sparse aperture. Problem 1 challenges the research community to make the best possible 3D SAR image from a sparse aperture. The second challenge, "Problem 2: Limited Bandwidth" asks to generate the best possible 2D image from bandwidth restricted data given two sets of k-space data from a 110° azimuth cut at an elevation of 0° and 30°. The third and final challenge is "Problem 3: Polarization" where given k-space data with 3 different polarizations: HH, HV, and VV, find innovative ways to use diverse polarization information. A summary of the challenge problems is shown in Figure 1.

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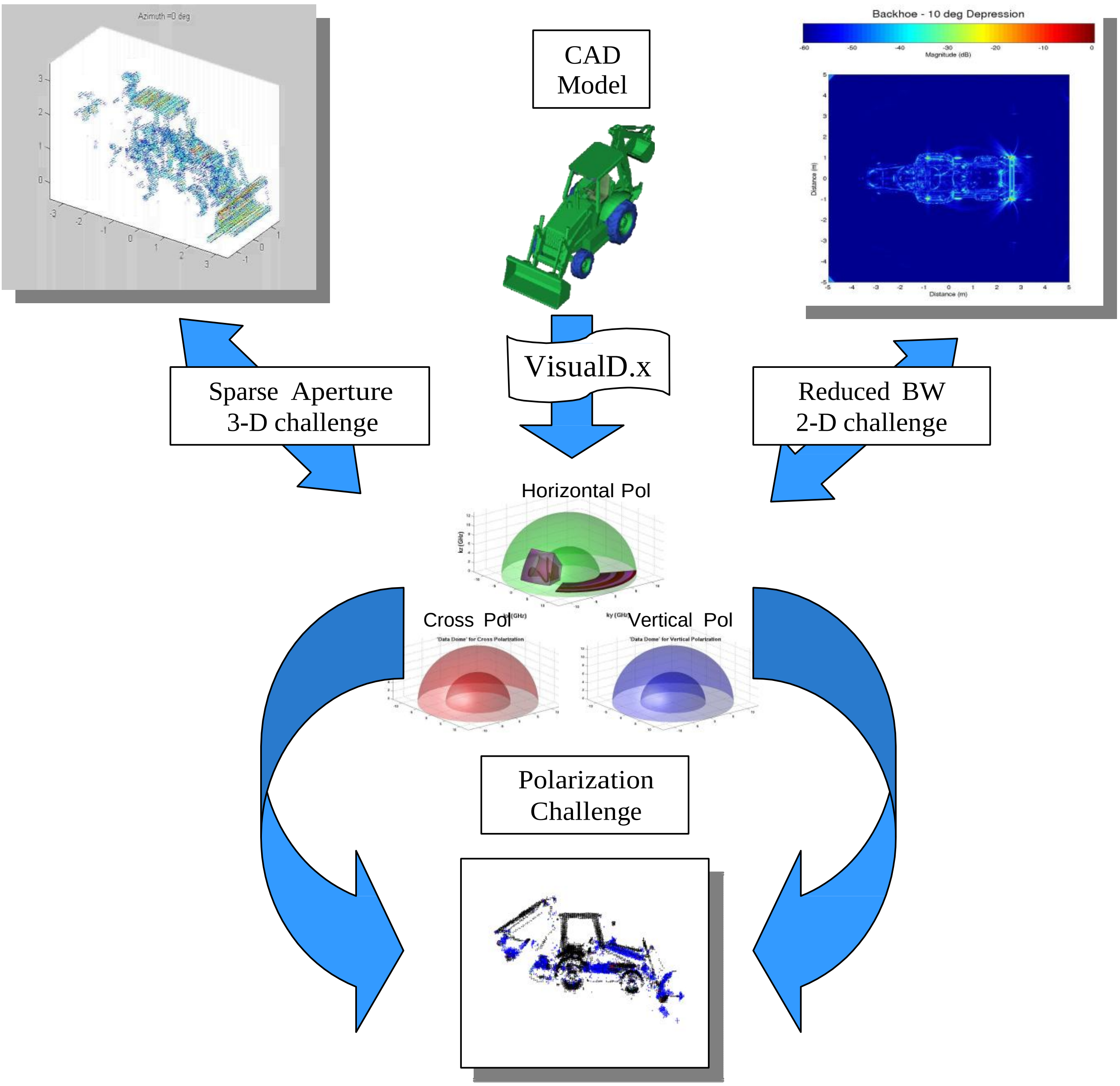

Figure 1: Challenge Problem Overview

2. DATA

The backhoe data set occupies 90GB of disk space. It was generated at SAIC's Champaign, IL site using a special version of Xpatch^{TM} called visuald.x. The data is simulated wideband (7-13GHz), complex backscatter data from a backhoe vehicle in free space as shown in Figure 1.

Figure 2: Backhoe Vehicle

It was generated over a full 2π steradian viewing hemisphere as shown below in Figure 2.

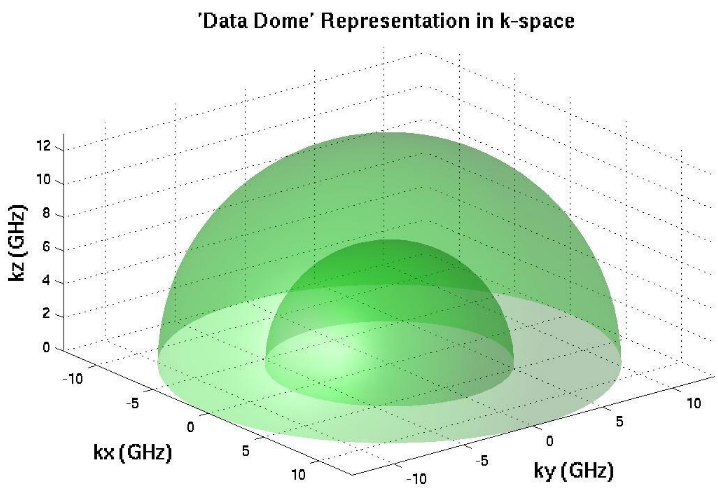

Figure 3: Data Dome Set

There are 14 samples per degree in both azimuth and elevation, one sample every 11.75 MHz in frequency and full polarization. The output of visuald.x, which are .ss files, was converted to Matlab^{TM}-native binary format, .mat files. This data has been approved for public release and the public release number is ASC 04-0273. To request a copy of the full backhoe data set, visit the AFRL/SNA Sensor Data Management System (SDMS) public website at http://www.mbvlab.wpafb.af.mil/public/sdms/main.htm. Requestors are responsible for providing a disk drive to hold the data. The website contains required hard drive specifications and contact information. Researchers can also request the DVD which contains the challenge problem including data and challenge problem descriptions through the website stated above.

2. PROBLEM 1: SPARSE APERTURE AND 3D PROBLEMS

Summary: Make the best possible 3D SAR image from a sparse aperture.

A sensor collects data with look angles following a meandering path in azimuth and elevation. The path lies totally within a box centered at azimuth of 90° and elevation of 30°. The box is 48° wide in azimuth and 24° wide in elevation. An example is shown in Figure 4.

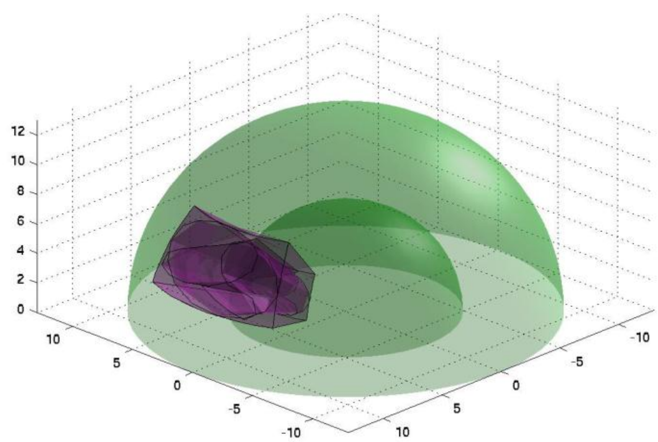

Figure 4: Sparse Aperture in Data Wedge

A close-up of the meandering path, affectionaly named "squiggle" is shown in detail below along with the details of the data points that comprise the squiggle.

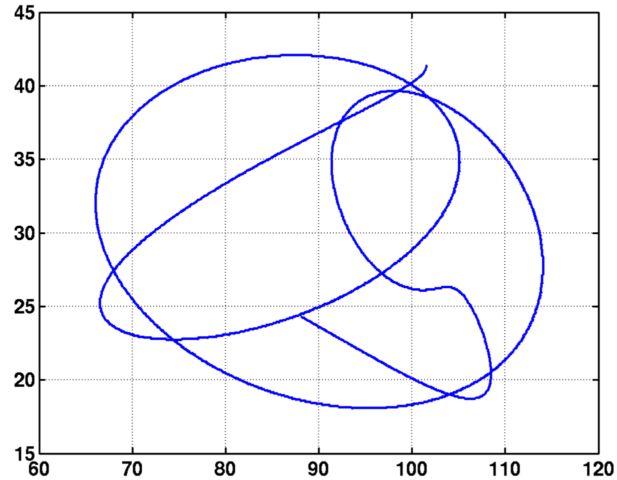

Figure 5: Squiggle

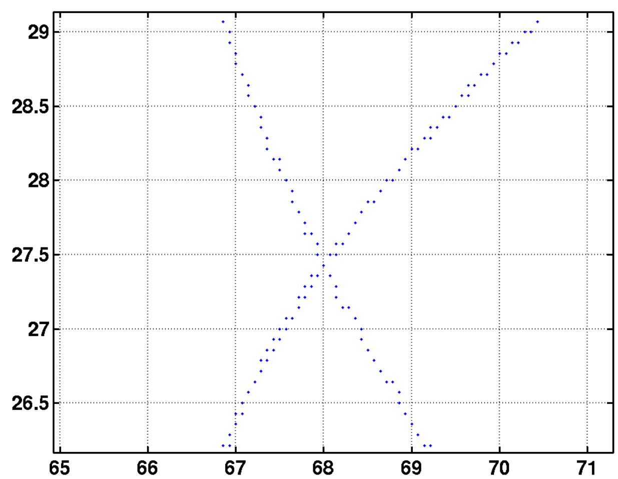

Figure 6: Squiggle Detail

The challenge is make the best possible 3D SAR image of the backhoe vehicle out of the data. The file movie "backhoe_30EL_90AZ.avi" contained in the DVD, is an example of the type of 3D image that can be generated if all of the data in the rectangular aperture is used, which is made by combining 12 8° by 8° 3D images spanning the entire 48° by 24° aperture.

The directory wedge contains 1152 Matlab™ binary files (*.mat) with each file containing the k-space data for one square degree. The filenames are indicative of the data they contain. For example, "backhoe_el30_az090.mat" contains the data between 29.5° and 30.5° for elevation and 89.5° and 90.5° for azimuth. Loading one of the .mat files gives a single structure data. The field data.vv is vertical polarization data, data.hh is horizontal and data.vhhv is cross polarization data. The data are 3D complex arrays of 512 by 14 by 14. The first dimension is frequency evenly spaced between 7 and 13 GHz, the second dimension is elevation and the 3rd dimension is azimuth. On the DVD, the file "getbackhoe.m" is a Matlab™ script that reads a data file(.mat) by specifying its k-space center and the file, “squiggle.mat” contains the azimuth/elevation pairs of a randomly generated path. The values match exact values found in the k-space data so interpolation is not required.

3. PROBLEM 2: LIMITED BANDWIDTH

Summary: Make the best possible 2D image from bandwidth restricted data.

One is given two sets of k-space data from a 110° azimuth cut: one set at 0° elevation and another set at 30° elevation. The azimuth range is from 350°(-10° azimuth) to 100° azimuth. The data covers 6 GHz of bandwidth permitting the formation of a very high resolution 2D SAR image at 0° elevation. The file, “backhoe_2D_benchmark.png” contained in the DVD as well as in Figure 8, shows a benchmark image formed from this data. The challenge is to make the best possible image with bandwidth limitations of the 6 GHz.

The following bandwidths are asked to be considered: 500MHz, 1 GHz, 2 GHz, and 4 GHz, and all should be centered about 10 GHz. In addition, included on the DVD, is a file, “spectrus_interruptus.mat” which contains the variables, bw30 and bw70, which describe spectrum availability at 30% and 70%, respectively. To explain further, bw30 has 30% of the spectrum unavailable and bw70 has 70% of the bandwidth unavailable.

Two sub challenges were posed within Challenge #2.

2a) Repeat the limited bandwidth challenge using the 30° elevation data instead of the 0° elevation data.

2b) Utilize the full bandwidth and full 100° aperture at 0° elevation and create a more optical-quality or literal image than the image contained in the file, “backhoe_2D_benchmark.png”.

The following data files are included for this challenge: “backhoe_el000_az350to100.mat” contains data from a 110° azimuth cut at 0° elevation; “backhoe_el030_az350to100.mat” contains data from a 110° azimuth cut at 30° elevation(for sub challenge 2a).

4. PROBLEM 3: POLARIZATION

This challenge is more unstructured than those mentioned in Sections 2 and 3. The main objective is how to incorporate polarization information. The k-space data given on the DVD is for 3 polarizations: HH(transmit horizontal linear polarization and receive same), VV(transmit vertical linear polarization and receive the same), and HV(transmit horizontal and receive vertical). We are looking to the research community to find innovative ways to incorporate polarization information in two ways: 1) Discover and describe target features revealed by polarization, 2) Incorporate polarization into imagery.

5. PROBLEM 4: FINAL CHALLENGE

The final challenge is to request the research community to go out and “do great things” with the data. Some ideas are to utilize the data to test concepts in waveform design, innovative conops, transient motion analysis or whatever peaks your interest. We hope that the research community will use the data in ways that will both surprise and delight us.

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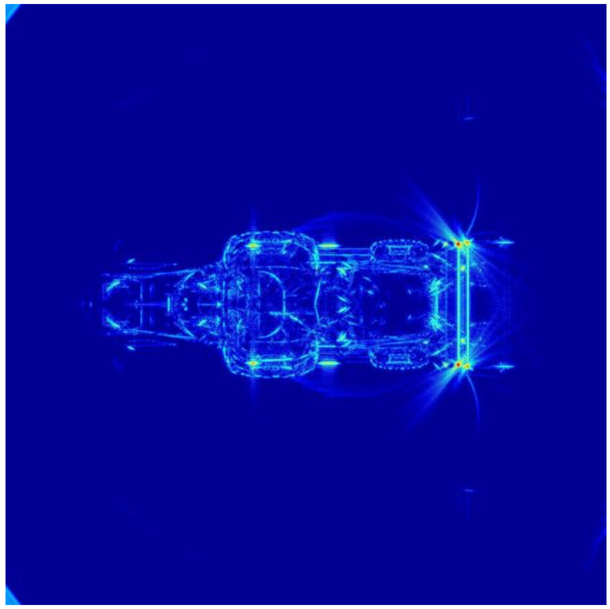

Figure 7: 2D Image at 360 Degree Aperture at 10 Degree elevation

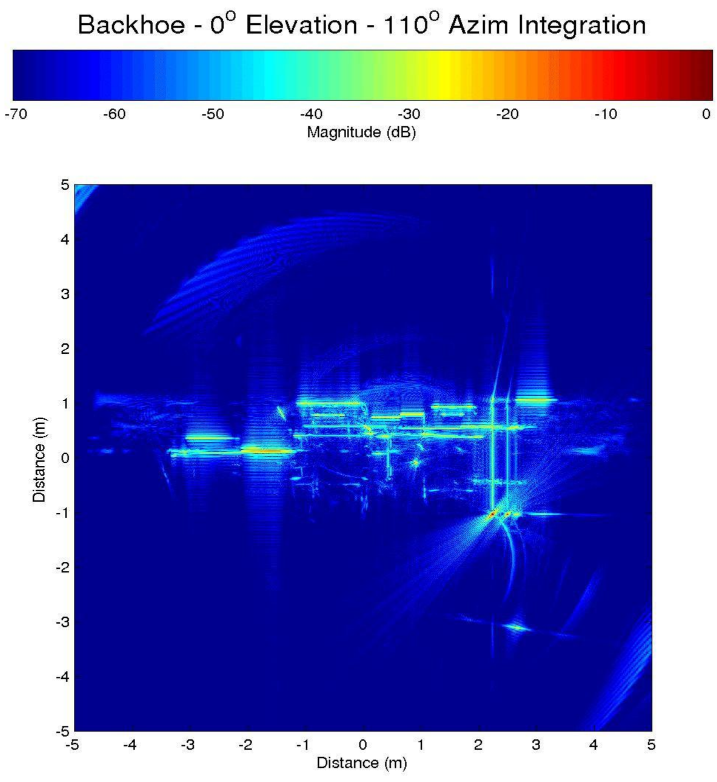

Figure 8: 2D Image at 110 Degree Aperture at 0 Degree Elevation

6. CONCLUSIONS

Each of the challenges, we hope will be just the starting point for great new ideas and research areas. Data can be requested as stated in Section 2: Data.