Generation of a Combined Dataset of Simulated Radar and EO/IR Imagery

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ABSTRACT

In the world of remote sensing, both radar and EO/IR (electro-optical/infrared) sensors carry with them unique information useful to the imaging community. Radar has the capability of imaging through all types of weather, day or night. EO/IR produces radiance maps and frequently images at much finer resolution than radar. While each of these systems is valuable to imaging, there exists unknown territory in the imaging community as to the value added in combining the best of both these worlds. This work will begin to explore the challenges in simulating a scene in both a radar tool called Xpatch and an EO/IR tool called DIRSIG (Digital Imaging and Remote Sensing Image Generation). The capabilities and limitations inherent to both radar and EO/IR are similar in the image simulation tools, so the work done in a simulated environment will carry over to the real-world environment as well. The goal of this effort is to demonstrate an environment where EO/IR and radar images of common scenes can be simulated. Once demonstrated, this environment would be used to facilitate trade studies of various multi-sensor instrument design and exploitation algorithm concepts. The synthetic data generated will be compared to existing measured data to demonstrate the validity of the experiment.

Keywords: Synthetic aperture radar (SAR), electro-optical/infrared (EO/IR), synthetic imagery, DIRSIG, Xpatch

1. INTRODUCTION

Remote sensing has been an ongoing effort for decades, both in electro-optical/infrared (EO/IR) imaging and radar imaging. Many advances in technology have led to better resolution, increased spatial and spectral coverage, faster analysis of the downloaded images, and automated means by which to perform certain types of analysis on the data. While there has been an extensive amount of work done in radar and EO/IR imaging separately, there has been less work done in combining the technologies.

Radar offers information, such as ranging and dielectric properties, that EO/IR imaging does not. Furthermore, it can penetrate many types of weather, to include rain, clouds and fog and it can be used to image day or night. Radar can also penetrate foliage to detect targets that may be obscured beneath. On the other hand, EO/IR imaging affords the user information about radiances and reflectances. It tends to have much finer spatial resolution than radar and therefore is capable of subpixel target detection, but is limited by weather, daytime imaging conditions (except in the case of short wave infrared, which can image at night), and often can only image at or near nadir viewing geometry. With these advantages and disadvantages of both types of imaging systems, it is reasonable to expect that combining the two systems in some way, whether as one sensor or by fusing resulting images, might yield more information than either one alone.[1]

Obtaining actual radar or EO/IR data can be costly and time-consuming. Therefore, it makes sense to take advantage of image simulation tools, such as Xpatch for radar and DIRSIG (Digital Imaging and Remote Sensing Image Generation) for EO/IR.[2] DIRSIG is an image generation model developed by the Digital Imaging and Remote Sensing (DIRS) Laboratory at the Rochester Institute of Technology. It is capable of producing simulated imagery in the regions spanning visible to infrared. [2] Xpatch is a similar image generation tool except that it simulates imagery in the

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radar region. It was developed by DEMACO, Inc, which is now part of SAIC.[3] Much work can be done using simulated data to test algorithms or theories before spending the resources on the real data only to determine that the algorithm or theory was invalid. [2]

The purposes of this research effort are to produce valid computer-aided design (CAD) geometries for a scene, correctly render that scene in both Xpatch and DIRSIG, and compare the synthetic data to measured data. The next step would be to register and fuse the images and determine the synergistic value of the combined images versus the individual ones. It is of critical importance to correctly model the geometry in both tools so that the resulting scenes are accurate. The challenges encountered and documented in building the CAD models and obtaining accurate synthetic data in both tools should help further the research in the area of combining EO/IR and radar data. When many of those challenges are worked through and it is possible to fuse the images, the hope is that the end result of the combined images will be more valuable than each of the separate images. The distinct differences in results that each of the systems produces should generate a product that contains more information than could be had out of either of the separate images.

2. DIRSIG

Digital Imaging and Remote Sensing Image Generation, or DIRSIG, is a synthetic image generation tool developed in the Digital Imaging and Remote Sensing (DIRS) Laboratory at Rochester Institute of Technology (RIT). The tool was designed to model broadband, multi-spectral and hyper-spectral imagery using principles such as bi-directional reflectance distribution function (BRDF) predictions and the geometry of a line scanner. Using programs such as MODTRAN and FASCODE, images can be simulated that are radiometrically accurate for a user-defined number of bandpasses.[2]

One of the main goals in the development of DIRSIG was to create a tool that could accurately represent real-world imagery from a variety of sensors for use in testing various algorithms. Since the cost of performing live data collects with actual sensors for the purposes of testing algorithms is so high, tools such as DIRSIG can help accomplish the same end result at a significant cost savings. The resulting images from DIRSIG are capable of representing mixed pixels, different illumination conditions, and real-world spectral characteristics using first principles-based approaches. Theories fundamental to chemistry, physics and mathematics are used to predict such things as the interactions between light and matter, the behavior of photons with various materials, and surface temperatures based on conductivity, density, convective loadings, etc.[2] It should be noted that simulated imagery is only a cost-effective tool to test algorithms and should not be used to completely replace the use of actual imagery for validation.

An enhanced CAD environment is used to generate every object in a scene in DIRSIG that has not been purchased from a commercial drawing company. Constructing a scene is a difficult process. First, the area to be modeled must be chosen and terrain data must be generated or located for that area. The CAD model is comprised of facets, or two-dimensional polygons that describe the object. This process can result in tens of thousands of individual facets for very detailed objects. Using a program called Bulldozer that is part of DIRSIG, each facet is assigned optical and thermodynamic properties that represent the material of the facet. Once the scene is attributed with the appropriate properties, Bulldozer is used to export to a Geometric Database file, which is the DIRSIG-recognizable scene format. A configuration file is then created in DIRSIG to simulate a sensor that will image the scene and the simulation is executed.[2]

DIRSIG tries to accurately model scenes through various approaches that model real-world occurrences. MODTRAN is an atmospheric radiative transfer code used to predict path transmissions and radiances within the atmosphere.[2] FASCODE is similar to MODTRAN, however it works as a line-by-line model rather than a band model, as MODTRAN does.[2] It is also useful for finer spectral resolution modeling than MODTRAN. However, it does not include the scattering support of MODTRAN, therefore modeling at shorter wavelengths can be affected. Other factors taken into consideration in DIRSIG are the effects of neighboring objects on each other, path geometry, atmospheric scattering, downwelled and upwelled radiances, and path length.

Spatial variations in reflectance account for the appearance of texture in real imagery. Therefore, DIRSIG utilizes a database of reflectance curves for each of the materials in the simulated imagery to model the appearance of texture. DIRSIG also uses bi-directional reflectance models to account for variances due to orientation and surface structure.[2] Surface temperature affects the texture in the thermal region, and this is accounted for by modeling the solar absorption and thermal emissivity through a convolution with a blackbody distribution.[2]

DIRSIG is based on a ray tracing approach to correctly account for geometric effects on the incident and emitted radiation in the model at each facet of an object. A ray is cast into the scene from each pixel at the focal plane of the sensor and each interaction the ray encounters is recorded. The recorded ray is then cast at the sun to determine the proper solar shadowing for the specified time of day, and any solar loading for up to 24 hours previous are taken into account. Rays are also cast from the facet to the hemisphere above the target to account for the downwelled radiance received by the target. A BRDF database can be included in DIRSIG for each material in a scene. DIRSIG utilizes approximately 100 rays that are simultaneously cast into the hemisphere to include radiances from both sky and background sources. These radiances are correctly weighted by each of their respective reflectances.[2]

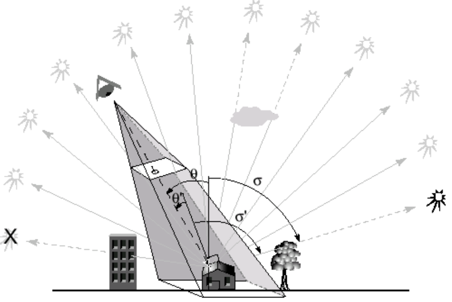


Fig. 1 DIRSIG ray tracing[4]

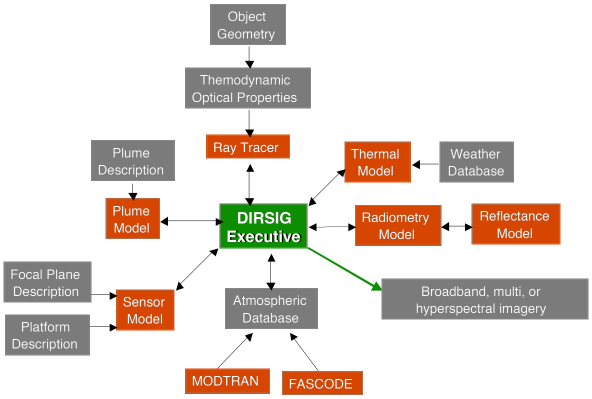


Fig. 2 DIRSIG submodel interactions[4]

DIRSIG is a robust EO/IR simulation tool that is widely used in the community and has many similarities to Xpatch, the radar simulation tool used in this research. Therefore, it was a sensible choice as the electro-optical simulation tool for this research.

3. XPATCH

Xpatch is similar to DIRSIG, in that it is a simulation tool, the difference being that it is for simulating radar imaging, rather than EO/IR imaging. Objects are represented in a computer-aided design (CAD) format and Xpatch is used to predict their radar signature and high frequency electromagnetic scattering. The tool was developed by DEMACO (purchased by SAIC in 1998) under the tri-Service sponsorship of Wright Laboratory at Wright-Patterson AFB, Phillips Laboratory at Kirtland AFB, the Army Research Laboratory at Ft. Belvoir, and the Naval Air Warfare Center at Pt. Mugu.

The Xpatch tool is an approximate solver and does not produce answers exact to actual scattering theory. The basic premise behind Xpatch's capability for radar image simulation is to calculate the polarimetric return from complex geometries of objects in a CAD format using the high frequency shooting and bouncing ray (SBR) technique. In calculating the ray geometry, the most time-consuming aspect is the first bounce, since shadows and blockage checks must be performed. After this occurs, Physical Optics (PO) is used to determine the contribution of the first bounce.[5]

Similar to DIRSIG, millions of parallel rays are projected toward the object to calculate the multiple-bounce effects. Each ray is traced by geometric optics (GO), taking into account reflection coefficients, polarization, and ray divergence, and all the rays are then summed to determine the final scattered field. At the last hit point, PO is used to do the integration. Seventy percent of the computation time in Xpatch is spent on ray tracing.

Xpatch is used to predict four kinds of radar signatures: Radar Cross Section (RCS), Range Profile, Synthetic Aperture Radar (SAR) Images, and Scattering Centers. RCS is a 1-D representation, SAR a 2-D, and Scattering Centers a 3-D representation. Xpatch describes RCS in terms of polarization. The outputs the user will obtain when running Xpatch to output an RCS is a list of four polarizations (VV, HH, VH, HV) for each of the frequencies and look angles that were input into the model. The format of the polarizations is such that the first letter is the resulting polarization scattering and the second letter is the scattering due to the incident polarization. For example, HV would be horizontal polarization scattering due to vertical polarization incidence.

When Xpatch is instructed to output the range profile for a target, it outputs a 1-D representation, depicting the returns as a function of time along the length of the target. A single look angle and sweeping frequency are the necessary user inputs to obtain a range profile. A SAR image presents a clear physical picture of the scattering, since it is represented in 2-D. Radar scattering from real targets is a vector sum and is sensitive to small changes in the target and environment. A SAR image gives the phase history data of a target in both the cross range and along-track directions.

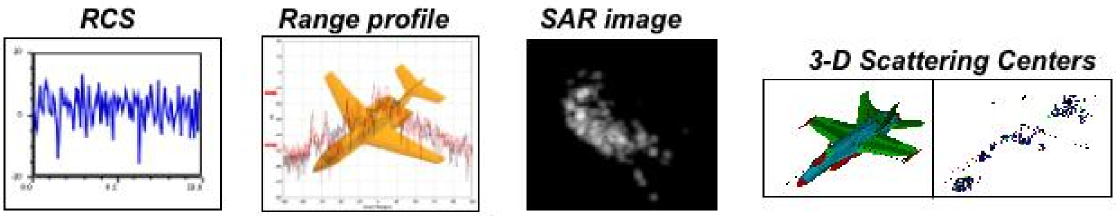


Fig. 3 Xpatch outputs[3]

The first step in using Xpatch is to give it a geometrical input of an object, which would be represented in CAD as either a faceted model or an IGES (Initial Graphics Exchange Specification) model. This is the most difficult step because the user has to know where the objects surfaces are and what those surfaces are made of material-wise. The CAD representation must be as close to real life as possible since any difference in angle or material will result in a different return than the real object would produce for a given radar system.

Xpatch is a high frequency model that uses the physical theory of diffraction (PTD), geometrical theory of diffraction (GTD) and the shooting and bouncing ray technique (SBR), which implements both GTD and PTD. These are all approximations of Maxwell's Equations, and therefore will give an approximate solution. Xpatch also has the capability of producing exact solutions, using full wave theory, such as MoM (method of moments), FEM (finite element moments), and FDTD (finite difference time domain). However, these are all very computationally intensive and in some cases could take months or even years to solve exactly. Therefore, the approximate solutions are a more attractive method. It should be noted that the approximate solutions are only valid in Xpatch for electrically large objects (~10λ or larger). Leaves of a tree, for example, would not produce accurate returns in Xpatch unless the frequency was extremely high, which would result in very small wavelengths.

3.1. Pre- and Post-Processing Tools

The graphical users interface (GUI) of Xpatch is actually a compilation of multiple pre- and post-processing tools that the user may employ on the data. These analysis tools are: cifer, XEdge, xyplot, McImage and XSignal. Cifer is a translation tool that allows the user to convert one type of CAD format into another. It also has the capability of texturizing existing geometries to make a ground plane behave more like grass, for example.

The XEdge tool allows the user to view the CAD geometry from any angle, as a solid geometry or a wireframe. The wireframe option depicts all the facets of the object, if it is a facetized model. The user can also shoot multiple rays at the geometry from a specified look angle to determine if the bounces seem reasonable, which will help the user to determine if there are errors in the CAD model.

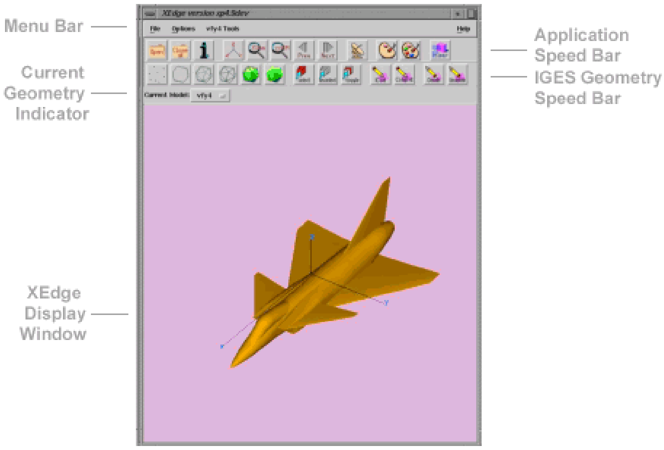


Fig. 4 XEdge GUI[3]

Xyplot is a post-processing tool used to model the resulting data in the form of x-y plots. Some of the options included in this tool are the ability to depict multiple data sets on one plot as well as view the data list, in the form of an ASCII file format. Another tool similar to xyplot, called Pioneer, affords the user the ability to save plots as any number of common image formats, such as JPEG. Pioneer is a powerful post-processing tool used for data visualization and comparison of synthetic and measured data. Pioneer allows the user to import data files from various sources such as Xpatch, measured data sources, or even Pioneer itself. It is an extremely useful tool for comparing measured and synthetic data. The outputs of Pioneer can be a variety of graphs, to include X-Y plots, image plots, and 3-D geometry viewing. These can all be saved as JPEG or other format for use in other applications. There is also multimedia capability within Pioneer so the user can record an MPEG or AVI format movie of Pioneer cycling through a graph at sweeping frequencies, for example.

McImage is used to display the CAD file along with the measured and predicted time domain signatures to view the effects of scattering. McImage is useful in that it allows the user to overlay the CAD geometry on the resulting plots so that the cause and effect of scattering are more easily visualized.

XSignal is a tool used to calculate and evaluate resulting signatures from the Xpatch simulation. It allows for the comparison of RCS, range profiles and SAR imagery. Once the signatures are added to XSignal the user then defines the error metric that will be used to compute the error of the signatures.

ModelMan, another tool within Xpatch, has the capability to read and write facet geometries as well as to organize facets or groups of facets into a visual tree. This grouping allows the user to manipulate many facets grouped as one in a variety of ways. For example, if the geometry is a military tank, the user can group the facets that comprise the turret into one group and manipulate the turret as a whole. ModelMan allows the user to articulate these groups as well. The turret could be articulated to be modeled at many different azimuth and elevation angles. Material properties can also be defined for the various facets in a geometry using ModelMan. Edge extraction is another capability of ModelMan for the purposes of obtaining accurate radar returns when edge effects must be considered. Both of these capabilities are available in other parts of Xpatch, however it is convenient to be able to manipulate both of these in the same part of the tool, and the edge extraction tool is somewhat more intuitive in ModelMan.

4. YOGI EXPERIMENT

YOGI (Yellowstone Optical and SAR Ground Imaging) is the dataset associated with a multi-agency data collection effort for an area just outside of Yellowstone National Park. This is the dataset that was used as the basis for the simulated EO and SAR imagery. Analysis of the YOGI dataset is funded by AFRL/SN (Air Force Research Laboratory/Sensors) under RASER (Revolutionary Automatic Target Recognition and SEnsor Research). RASER is a program through which AFRL supports research efforts. RIT is one organization under RASER receiving money to analyze the YOGI data. These data are available to support a statement of work entitled “Mathematical Modeling and Fusion of Hyperspectral and Synthetic Aperture Radar Data in Open and Urban Landscapes.”[6] The work is a funded effort and will attempt to generate synthetic imagery for the area and combine the SAR and hyperspectral data into a fused image.

The organizations involved in this data collection effort included the Naval Research Laboratory (NRL) Optical Sciences Division, MIT Lincoln Laboratory, Defense Advanced Research Projects Agency (DARPA) Information Exploitation Office, HyPerspectives/Yellowstone Ecological Research Center, JPSD Rapid Terrain Visualization Program, Air Force Research Laboratory, U.S. Forest Service and Yellowstone National Park. The data collection occurred in the summer of 2003, involving a multitude of sensors. Some of the objectives of the data collection were: development and assessment of a terrain characterization algorithm, development of a change detection algorithm, and modeling of terrain height.[7]

Calibration of the sensors was accomplished through various man-made objects such as aluminum corner reflectors, fabric panels, and tarps. Other objects imaged included cars, trucks, SUVs and other vehicles. Some were camouflaged, others were not, and they were in various locations that included out in the open or under foliage. The corner reflectors and a Volkswagen Microbus were chosen as the targets to simulate in DIRSIG and Xpatch.

5. SENSORS

As mentioned above, the YOGI experiment was a multisensor data collection effort. NRL flew three optical systems on a P-3 aircraft: the WARHORSE VNIR hyperspectral imaging sensor, the IRONHORSE SWIR hyperspectral imaging sensor, and the CA-270 EO-IR dual band reconnaissance camera. An Army RC-12 flew a VHF/UHF SAR system. RTV used a King Air to fly their LIDAR optical sensor and a DH-7 to fly their IFSAR sensor. NASA/JPL used a DC-8 to fly a SAR system and a twin engine Cessna was used with the HyMap optical sensors.

The work done for this paper modeled the NRL WARHORSE and the RTV IFSAR sensors, therefore only those will be discussed in more detail. NRL’s WARHORSE (Wide Area Reconnaissance Hyperspectral Overhead Real-Time Surveillance Experiment) is a VNIR (visible near infrared) hyperspectral instrument. It is a pushbroom sensor that has a 1024x1024 Silicon Mountain Designs CCD camera and an American Holographic grating spectrometer. It operates at 40-60 Hz, with 1024 cross-track spatial pixels and 64 wavelength bands.[7] The reader should refer to Table 1 for more detailed sensor specifications.

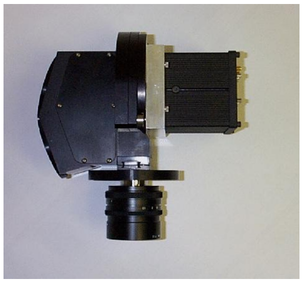


Fig. 5 NRL WARHORSE[7]

CCD Camera	1024 x 1024 silicon CCD
Front-End Optics	75 mm lens
Field-of-view	9.3 degrees
Cross-Track IFOV	0.16 mrad
Spectral Range	500 – 950 nm
Spectral Bandwidth	11.4 nm (binned 8x1)
Spatial Pixels	1024
Spectral Channels	64
Frame Rate	40 frames/second
Scan Rate	0.025 seconds
Detector Element Size	0.012 mm
GSD	1.86 ft (0.566 m)
Swath width	1900 ft (579.12 m)

Table 1 WARHORSE specifications[7,8]

The IFSAR (Interferometric Synthetic Aperture Radar) sensor was developed by Sandia National Laboratories. It is capable of imaging in four bands: Ka, Ku, X and VHF/UHF. During the YOGI collect, it operated in the Ku band at 16.7 GHz. The IFSAR sensor is capable of operating at a wide range of resolutions, depression angles, ranges and squint angles. VV and HH polarizations are both available when operating in the Ku band. Overlapped subaperture image-formation and phase gradient autofocus algorithms allow the IFSAR to form images in real time.[8]

Capabilities	All weather, day/night operations
Swath width	1300 m
Frequency	16.7 Ghz (2 cm wavelength) Ku band
DEM GSD	3 m
Backscatter	0.75 m
Absolute vertical accuracy	1.4 m

Table 2 Sandia IFSAR specifications[7]

6. BASIC SCENE DEVELOPMENT FOR DIRSIG

Part of the data collection in YOGI occurred at a place called Fisher Creek, an area that is located about midway between the bottom of a valley and Sheep Mountain. This area consisted of various types of land cover, including dirt and gravel roads and trails, densely forested areas, open grassy areas, regenerating areas from fires, and downed wood. Various objects, or targets, were imaged throughout this area as part of the data collection. The first scene constructed for the research that is the focus of this paper consisted of a 16-foot trihedral corner reflector, to model the actual corner reflector in the YOGI dataset in an open area of Fisher Creek. The corner reflector was constructed in a computer aided design (CAD) program called Rhinoceros, or Rhino. In addition to the corner reflector, a flat plate was also constructed in Rhino, upon which the corner reflector sat. Using Bulldozer, the tool within DIRSIG, the corner reflector was attributed with aluminum and placed flat on the middle of the plate, which was attributed with grass material. The model of the corner reflector on the plate can be seen in Figure 6. An image of the actual corner reflector used in the YOGI dataset can be seen in Figure 7, however the reflector modeled was one from an open field location.

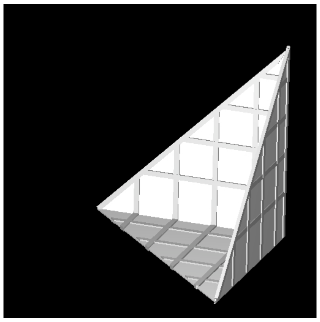


Fig. 6 CAD model of 16-foot corner reflector

Fig. 7 Actual 16-foot corner reflector from YOGI dataset

Additionally, the corner reflector as well as a Volkswagen Microbus were incorporated into a much larger scene that covered most of the Fisher Creek area and included the creek, trees, and other terrain. With the scenes constructed as a DIRSIG-compatible object database file (.odb), a configuration file (.cfg) was constructed to run with DIRSIG. It was configured to simulate July 28, 2003 at a ground altitude of 2.634 km and coordinates of latitude 45.041 and longitude –109.913, all of which was meant to model the YOGI dataset at Fisher Creek.[7] The environment was set to model a mid-latitude summer with 23 km visibility and no clouds or rain. The actual data was taken on a day of no rain and minimal to no clouds. Additionally, DIRSIG runs were executed that modeled a mid-latitude winter with 100 km visibility to determine if the increased visibility and decreased aerosols would improve the agreement between real and simulated data. The platform was set up to simulate the actual NRL WARHORSE sensor, with a focal length of 75 mm and a scan rate of 0.025 scans per second. The sensor was simulated to be flying at an altitude of 4419.60 m.

7. BASIC SCENE DEVELOPMENT FOR XPATCH

DIRSIG uses the CAD model in a .obj format that is turned into a .gdb format through the use of Bulldozer. The .obj format is an export type available in Rhino. Xpatch uses a .facet or .iges format as its input CAD model. Rhino has the ability to export in .iges but not in .facet, since that is an ACAD format, which is a different CAD program than the one available at RIT. However, the .iges export format is not compatible with Xpatch as is, and certain settings have to be used to make it compatible. These settings are available from SAIC, the distributor of Xpatch. However, it was found in this research that perhaps an anomaly with Rhino as it is installed at RIT prevents the user from creating an IGES format with the SAIC recommended settings. Therefore, exporting to .iges format from Rhino was not compatible with Xpatch. Instead, ModelMan, one of the auxiliary tools of Xpatch, was used to create a .facet format from a .raw format, which is an available export format of Rhino as well.

For the Xpatch input file, a SAR image run was set up with a center frequency of 16.7 GHz, to match the IFSAR sensor. The look angles were all set at an elevation angle of 45 degrees, viewing the inside of the corner reflector from one panel to the other in multiple looks. Originally, to cut down on run time, the corner reflector was modeled as PEC (perfectly electric conductor) material rather than aluminum.

8. EXPERIMENTAL RESULTS

After various iterations, including using texture and material maps within DIRSIG, the simulated imagery began to model the spectral characteristics of the WARHORSE imagery. Using the measured ground truth reflectivity data from various terrain in the real scene and incorporating it into the texturization of the DIRSIG background helped matched the spectral profiles of the real and simulated terrain as well. Figure 8 shows the DIRSIG simulated corner reflector alongside the WARHORSE sensed corner reflector. Figures 9 and 10 show the spectral profile comparisons of the real and simulated corner reflectors and terrain.

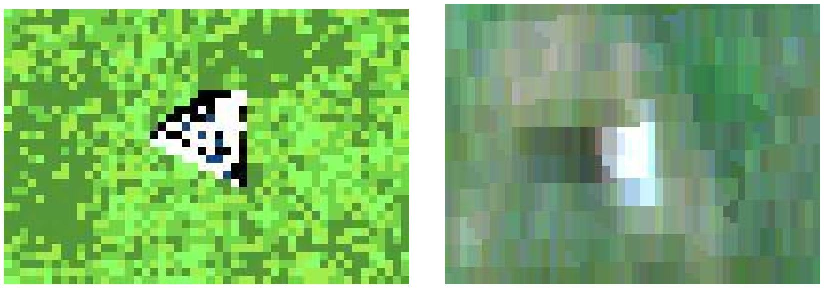
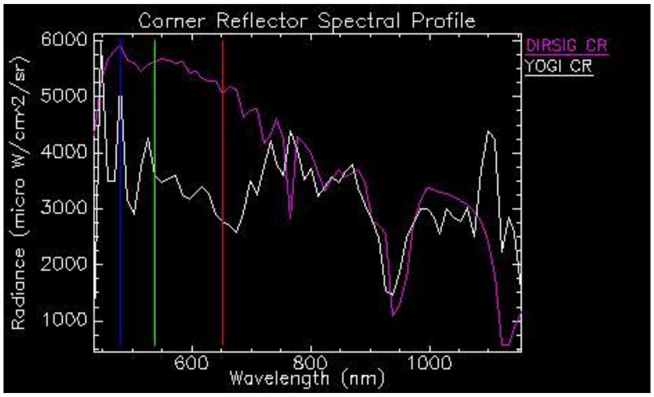


Fig. 8 DIRSIG simulated corner reflector (left) and WARHORSE corner reflector (right)



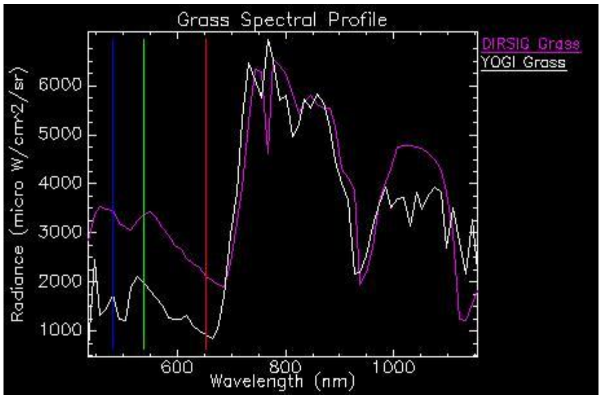


Fig. 9 Spectral profiles of corner reflectors (RMSE=5.83%)

Fig. 10 Spectral profiles of terrain (RMSE=4.93%)

It should be noted that while the terrain profiles match up closely, the corner reflector profiles exhibit some discrepancies. Between approximately 750 nm and 1100 nm, the profiles match up closely in both magnitude and shape. However, below 750 nm, the WARHORSE data exhibits a red edge that the simulated data does not. Part of the reason for the discrepancy is that the WARHORSE sensor produced very noisy data, which would be impossible to model exactly and would not afford the user any additional information. However, whether the red edge is part of the noise or a true spectral property of the corner reflector is not known at this time and further research into the necessity of matching the profiles exactly in order to produce acceptable simulated data is needed. The RMSE values are relative to the mean of the WARHORSE image.

The larger Fisher Creek scene was also simulated in DIRSIG. The results of the DIRSIG simulation as well as the actual WARHORSE image can be seen in Figures 11 and 12. Though the general composition and layout are similar, it should be noted that there are still areas that need further work. For example, the creek in the WARHORSE image is muddy, but in the DIRSIG image looks clear, therefore the material properties for that area need to be adjusted. Also, more trees need to be incorporated in the overall scene since they are sparse in the current simulation due to a need for faster run times. The material and spectral properties of the trees also need to be adjusted so they exhibit shapes that more closely match what is expected. Though the grass in the DIRSIG scene seems to exhibit more blue qualities than the WARHORSE scene, the spectral profiles shown in Figure 13 show that the grass is actually relatively accurate.

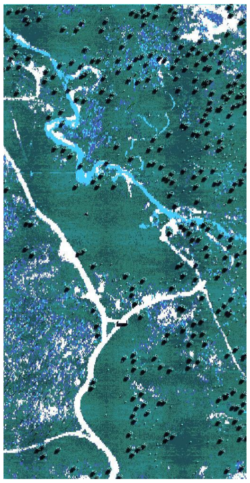


Fig. 11 DIRSIG Fisher Creek Scene

Fig. 12 WARHORSE Fisher Creek Scene

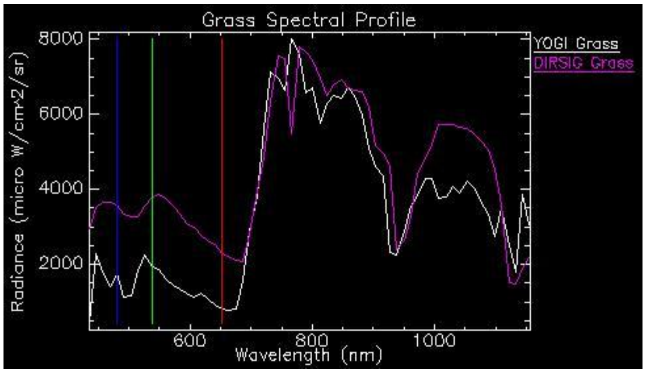


Fig. 13 Spectral profiles of Fisher Creek Terrain (RMSE=4.95%)

The CAD model of the corner reflector used in the DIRSIG simulations was also used in the Xpatch simulations. However, attempts to export the Rhino format to a format acceptable to Xpatch were unsuccessful, and therefore a tool within Xpatch, called ModelMan, was used to convert the Rhino CAD format to a facet format for Xpatch. The Sandia IFSAR image from the YOGI collect for Fisher Creek is shown in Figure 14 and the results of the Xpatch simulation of the corner reflector are shown in Figure 15.

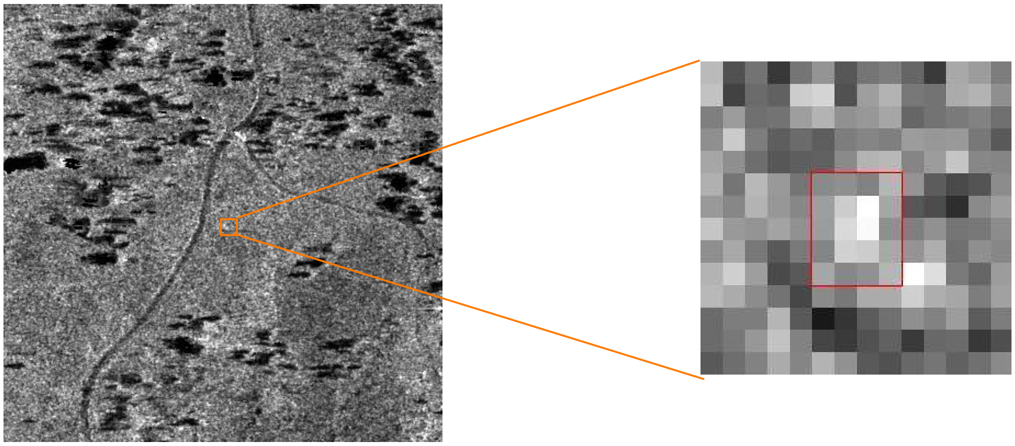


Fig. 14 Sandia IFSAR image of Fisher Creek with blown-up image of corner reflector shown to right. Pixels inside red box are the pixels considered to be the corner reflector returns.

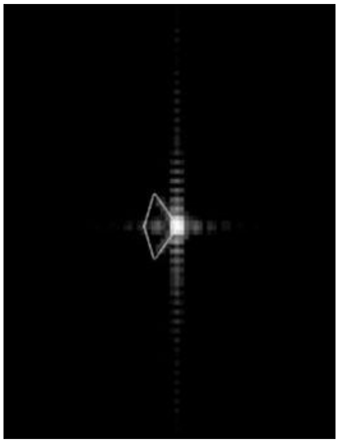


Fig. 15 Xpatch SAR image of PEC corner reflector (corner reflector shown as wire outline from 45 degree elevation angle)

The results of the Xpatch simulation were compared to the IFSAR data for a slice through the center of each image. The 20 pixels are shown in Figure 14 in the red box of the blown-up corner reflector. The results of the comparison are shown in Figure 17. The shapes look to follow a similar pattern, as well as exhibit the expected Sinc shape in general, however the Xpatch data is much higher in magnitude as compared to the IFSAR data. Part of the reason for the much higher return for the simulated data is that the Xpatch simulation modeled the corner reflector as PEC (perfectly electric conductor) material, which is expected to result in a much higher return. The corner reflector was attributed with aluminum material for the next run. However, since permittivity and permeability values for the aluminum in the actual corner reflector were not known, a best estimate had to be used. The results of the aluminum run are shown in Figure 16 and its comparison to the real corner reflector are also depicted in Figure 17. As expected, the return of the aluminum is lower than the PEC, bringing it closer to the behavior of the IFSAR data. For both Xpatch runs, the corner reflector was modeled as solid aluminum, rather than mesh. However, for future iterations, the material will be modeled as mesh and the corner reflector surroundings will be added as well. The more accurate material properties as well as the added clutter will tend to interfere with the return Sinc function, causing it to flatten out and appear more like the IFSAR data.

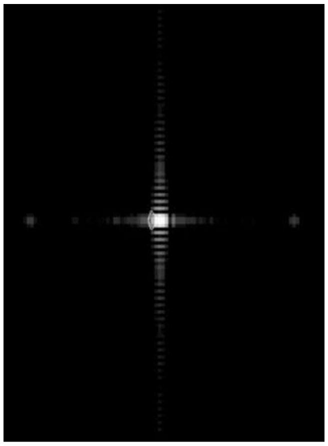


Fig. 16 Xpatch SAR image of aluminum corner reflector

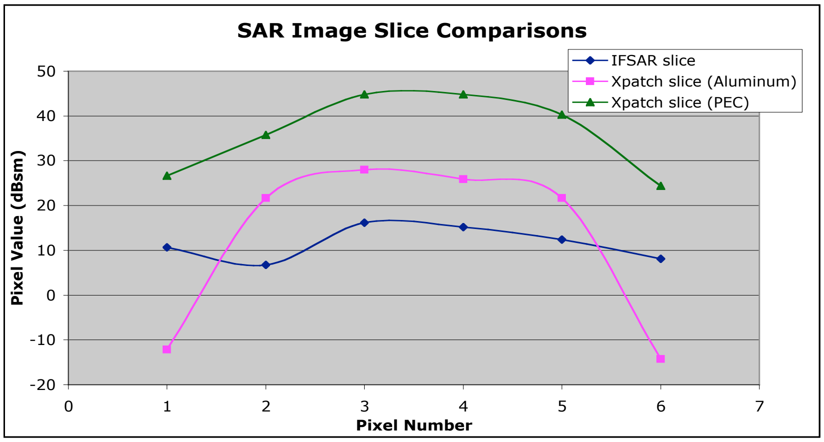


Fig. 17 Comparison of dBsm values of IFSAR and Xpatch data

9. CONCLUSIONS

Electro-optical and SAR simulation tools were used to generate synthetic imagery modeling a real scene extracted from a data collection that included both an optical and a SAR sensor. Setting the parameters in the synthetic environment to closely match those from the real data as well as understanding the characteristics of the sensors modeled resulted in synthetic imagery that accurately modeled the WARHORSE imagery. Further modifications need to be made in the SAR simulations to better model the IFSAR imagery. The issues in simulating imagery in both environments were determined to make future simulations less problematic. These simulated images as well as future images produced in a similar manner can be used to investigate the synergistic value of fusing optical and SAR products.

DISCLAIMER

The views expressed in this article are those of the authors and do not reflect the official policy or position of the U.S. Air Force, Department of Defense, or U.S. Government.

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