SRI International
Artificial Intelligence Center

Monthly Status Report #7	December 15, 1997
Monthly Status Report #8	January 15, 1997
Monthly Status Report #9	February 15, 1997

An Integrated Feasibility Demonstration for Automatic Population of Geospatial Databases

SRI Project Number:
ECU-1515

Contract Number:
NMA202-97-C-1004

DARPA Order Number:
E645

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Preface

The following tasks from our Statement of Work summarize the work being carried out by SRI International and its subcontractors GDE Systems and Vexcel Corp. on the DARPA Automatic Population of Geospatial Databases Integrated Feasibility Demonstration contract.[1] A description of our activities in the latest report-

[1] The information from the monthly reports from GDE and Vexcel has been integrated into this report. The full text of the the GDE and Vexcel reports are included as appendices for reference purposes.

ing period in support of each task follows the task description. Because of the late start of the program all scheduled reports and deliverables will be delayed three months from the schedule in our proposal.

This report is also available via the WWW at the URL `http://www.ai.sri.com/~apgd/reports/`.

1 Technology Development

1.1 Refine the BOS architecture

> *Review the current BOS architecture, enhance it, and distribute a description of it to the APGD community.* (Q1–2)

The high-level description of the architecture has been found to be effective and we plan no changes at this time.

Our current plan as described in previous reports and briefings involves instantiating components of the BOS Architecture needed for the first year demo, which will focus on road delineation. The architecture will select appropriate imagery from both SAR and EO coverage; will extract some of the necessary context from the output of the Land Cover Classifier; will invoke appropriate delineation algorithms from a set of at least six distinct linear and road delineation algorithms; will determine places where the correspondence between the 3-D road network and underlying DTED are inconsistent and will invoke intensification/integration techniques to resolve these.

1.2 Develop CBACS

> *Extend and enhance existing RADIUS HUB architecture to meet the requirements of the CBACS to serve as the control structure for invoking feature extraction algorithms.* (Q3–6)

Our plan for the first year demo is that the CBACS will control the algorithm flow. We are currently focusing on the specific specifications for the “algorithm wrappers” that CBACS uses to make its decisions. As part of the year one demonstration we will present the details of the CBACS control structure.

1.3 Develop feature extraction managers

> *Design and develop feature extraction managers for terrain, linear, area, compact 3-D features, and dynamic objects.* (Q3–4)

As we briefed, we feel that feature-specific editing is a necessary and integral part of the modeling process. The feature-specific editors are components of the respective FEMs. We are implementing the FEM for linear features, which will be described and demonstrated for the demonstration. As part of an IR&D effort GDE is producing an editor for buildings.

1.4 Survey automated model extraction techniques

> *Identify potential algorithms for improving the performance of planned or installed BOS feature extraction capabilities and extending the operating domain of existing algorithms.* (Q1–2)

We have completed the compilation of bibliographies for the three major feature extraction subsystems that we are currently concerned with. All three are available on the Virtual Lab. We also plan to augment these with summaries of the approaches.

1.5 Develop feature extraction and consistency enforcement algorithms

Adapt, integrate, and enhance IU algorithms for extracting terrain, linear features, area features, 3-D compact objects, and dynamic objects. Develop new techniques that capitalize on the complementary aspects of radar data and E-O and multi-spectral data. Adapt the Model-Based Optimization (MBO), deformable mesh, and consistency enforcement technology to work with extracted features and their attributes. (Q3–8+)

- Use SRI 3-D mesh technology for attributing and validating geometric structure of roads, including across- and along-path elevation profiles.
- Techniques for automatically cueing building as a precursor to 3-D modeling. Vexcel has developed automatic procedures using IFSAR and MS classification for this purpose. The results of this algorithm on the Ft. Benning dataset is 100%. These results have been distributed to GDE, UMass, and USC. We plan to extend the evaluation to other sites to verify the competence of the algorithms.
- Algorithms necessary for the high-resolution 3-D steps in the road modeling process have been been prototyped. Current work involves putting them under automatic control.
- We have begun extensions to the road delineation subsystem to handle street and roads in urban and suburban areas in addition to the rural environment characteristic of Ft. Benning.
- GDE has been extending the domain of applicability of their automatic building modeling system to a larger variety of building types. The goal for the first year demo is to raise the competence of the algorithms from the initial 50% to approximately 80% by the time of the demonstration.

1.6 Develop techniques for multi-sensor registration

Extend the Model-Supported Positioning technology to include radar imagery and multi-spectral imagery. These will co-register images from different modalities in a common coordinate system. Extend the sensor model API in the RCDE to provide a homogeneous interface to the full range of data, including the transformations to map back and forth between image coordinates and 3-D coordinates. Implement photogrammetrically rigorous error analysis and propagation facilities in the RCDE. (Q1–4)

We feel we have a fundamental understanding of the issue involved in registering E-O, MS and SAR to a common 3-D coordinate system. However, precise error estimates are generally unobtainable for SAR and MS, due to the nature of the current implementation of processing for the products. We are currently carrying out a study to predict and evaluate the results of current registration techniques to allow us to get reasonable error estimates needed to combine data from these multiple sources.

1.7 Refine the design of, and implement, the persistent store

Specify the data format (syntax and semantics) and API for the spatio-temporal database component of the BOS, based on the requirements derived from the selected SE and MSE applications. Implement the dynamic database component of the BOS. (Q1–4)

Current work involves:

- Implementing the import and export facilities for the persistent store to and from SOCET SET.
- Designing procedures for exporting our automatically generated terrain and feature models to the simulation databases employed by Synthetic Environment applications.

2 APGD Community Development and Technology Transfer

2.1 Produce, maintain, and distribute calibrated datasets to FRE and IUBA contractors

> *Collect, calibrate, and document classified and unclassified sets to be distributed to the community for experimental and evaluation purposes.* (Q1–8)

The dataset for Ft. Benning has been completed and was initially distributed in early November. A number of errors were uncovered in the distribution and corrected in subsequent releases. We continue to augment this data with new components as they become available to us.

It consist of the following:

- 15cm GSD panchromatic aerial survey images with control
- 15cm GSD orthomosaic
- 2.5m GSD SAR/IFSAR coverage mosaicked and rectified to UTM
- 0.4m GSD SAR/IFSAR coverage in SCH format for the MOUT area
- DMA DTED
- Dædalus MS collection
- classification results based on the above.

2.2 Construct and distribute ground-truth models

> *Interactively construct attributed, detailed 3D models of three sites (e.g. Ft. Hood, Ft. Irwin, and Ft. Benning) to be used for benchmarking and evaluation.* (Q1–8)

GDE has complete ground-data models of the buildings at selected locations in Ft. Hood. These will be used in the benchmarking facility for building extraction and will made available to the APGD community for self-evaluation.

Ground-data models are complete for the MOUT area and road network at Ft. Benning.

2.3 Develop evaluation metrics and procedures and perform evaluations

> *Design an evaluation process that can be used to identify significant advances in feature extraction or attribution. Enhance metering facilities currently available in the RCDE. Periodically run evaluations to document the current competence of the evolving system. These results will be posted on the network for comment and comparison.* (Q1–2)

A set of evaluation procedures and benchmarking tools have been completed and are currently being discussed with the program monitors and managers for community-wide use at Evaluation Day at Terrain Week '98. The current version will be employed for the first year demonstration.

2.4 Establish and maintain the APGD virtual lab

Provide continuous access to data, ground-truth models, and results on a WWW site. In this way, any group can compare its results with the current best results. (Q1–8+)

The Virtual Lab now contains facilities for remote execution of the SRI low-resolution linear delineation system and evaluation of linear delineation results.

This will make use of a "ground truth" reference image to test algorithms for accuracy in extraction of geometry and topology. Users can

- Download selected imagery and upload the results computed by their algorithms for evaluation.
- Provide their own imagery and "reference data" for execution and evaluation of the SRI algorithm.
- Use our SRI sample imagery and algorithm, with user-specified parameters to evaluate performance variations.
- Upload both imagery, reference data, and results for evaluation by our metrics.

It also allows access to all components of the Ft. Benning dataset.

2.5 Interface to FRE contractors

For each FRE, select one of the three partners to be the primary interface for that FRE. (Q1–8+)

GDE is working closely with USC to evaluate their multi-image building extraction system. They are also working the UMass to evaluate the results of Ascender II.

We have tried to contact Andy Lee of Harris regarding their building modelings techniques, but have not yet received any information.

Vexcel has distributed the results their building cueing algorithm to UMass and USC.

2.6 Develop and perform demonstration scenarios

Identify realistic processing scenarios and demonstrate prototype systems for them. Include scenarios and demonstrations for systems working with classified data. (Q4 & Q8)

A preliminary version of the planned demonstration was presented at SRI in December. This is being refined and extended for the first year demonstration at SRI in 4/98.

A plan for the demonstration was prepared and delivered to the government. This is included in Appendix C. Questions from the government and replies from SRI are included in Appendix C.

2.7 Transfer technology

> *Develop and carry out pilot insertions of the developed technology into existing systems, such as GDE's SOCET SET and Vexcel's mapping system.* (Q5–8)

We have been carrying out discussion with Michele Motsko to provide a copy of our year-one demonstration system for evaluation and experiments at NIMA.

Copies of the linear delineation software has been made available to USC, GDE, Vexcel, and UMass.

3 Meetings and Reports

We attended the APGD Workshop at Ft. Benning on 11/19 & 11/20. George Lukes, Michele Motsko and Doug Climenson were briefed on our activites at a meeting on 12/19 at SRI. We participated in the IU PI Meeting 2/1 – 2/3, where APGD was a major topic of discussion.

We conducted a TEM with GDE and Vexcel on 11/13.

We continue to coordinate efforts through weekly conference calls, in addition to email and in-person meetings as needed.

A GDE Monthly Report

APGD Monthly Report
December 10, 1997

Technical Section

Summary

Work during this period has again emphasized the benchmarking of building extraction algorithms, the generation of test data sets, and some work on automatic confidence metrics for building delineations.

Detailed Work Description (by SOW item):

1. ARCHITECTURE REFINEMENT No activity

2. ALGORITHM SURVEY We are continuing work on our summary of the state of the art in automated building extraction.

3. ALGORITHM DEVELOPMENT Work continued on confidence measure development.

4. MULTI-SENSOR REGISTRATION No activity

5. DYNAMIC DATABASE No activity

6. DATASET PRODUCTION & DISTRIBUTION Format difficulties with the distributed Fort Benning data set continue to plague us. We are working the problems and distributing corrections as fast as we can.

7. EVALUATIONS We are proceeding with the benchmarking process, using our defined procedure and test data sets. Some work is being done on editing procedures, based on GDE' IRAD-developed editor, in order to make the ''cost-of-editing'' metric more reliable.

8. INTERFACE TO FRE CONTRACTORS Interaction with USC is continuing during the benchmarking process.

9. DEMONSTRATION SCENARIOS Initial visualizations of Fort Hood and Fort Benning have been prepared on SOCET SET. Richer and more polished versions will be done using Rapid Scene.

10. TECHNOLOGY TRANSFER No activity

11. OPTION YEARS No activity

12. PROGRAM MANAGEMENT We are continuing to work according to the priorities agreed on with the prime. We keep in close contact with team members via weekly conference calls and e-mail communications as appropriate.

B Vexcel Monthly Reports

Automatic Population of Geospatial Databases
Monthly Report to SRI for November 1997

Bob Wilson
Vexcel Corporation
19 December 1997

1. MAJOR TECHNICAL ACCOMPLISHMENTS

1.1 Evaluations Using Ft. Benning ARC/INFO Data

We obtained an extensive collection of ARC/INFO data layers for the McKenna MOUT site at Ft. Benning, GA. It includes vector layers describing stands of trees, bodies of water, building footprints, road delineations, drainage lines, etc. We have rasterized some of these data so we can compare them with the Land Cover Classification (LCC) produced by Vexcel's IFMAP software, but they often lack the resolution required to be good ground truth.

Nevertheless we have been able to devise a number of tests based on these data. We have compared the IFMAP thematic classes with rasterized ARC/INFO vegetation and building layers. We have compared IFSAR building heights with ARC/INFO attributes of buildings. We have compared tree heights with ARC/INFO attributes of forested regions.

I presented a summary of our results at the APGD Workshop at Ft. Benning.

1.2 Supplied Radar Coverage of Ft. Benning to GDE for Data Set

Contributed to the Ft. Benning data set compiled by GDE by sending IFSARE and Sandia Spotlight IFSAR coverage on tape.

1.3 Meeting at SRI to Prepare for APGD Workshop at Ft. Benning

On 13 November we met at SRI to discuss strategy for the meeting at Ft. Benning. A major topic of discussion was algorithm evaluation. The next day Marty demonstrated to me the performance of road delineation software on SAR imagery. I obtained a copy of the high-resolution orthomosaic of Ft. Benning and this has been very useful for our evaluation efforts.

1.4 APGD Workshop at Ft. Benning

I presented an overview of Vexcel's software for Land Cover Classification (LCC), estimating bald earth elevation, and estimating the height of trees and buildings. I also discussed ongoing evaluation of these algorithms.

I participated in the battlefield simulations. On our excursion through the woods I was able to identify a variety of things classified from IFSAR as "buildings" (or man-made objects). These included genuine man-made structures (e.g., tanks, a vehicle lying on its side) and dead trees in a swamp. All of these things give rise to a double-bounce radar return. I took a lot of photographs, but wish that I'd been able to roam even more extensively.

NIMA assured me that I would soon receive lots of reference data, but I was also cautioned that the data is of variable quality.

1.5 Report to Coworkers at Vexcel on APGD Workshop

Since so many folks at Vexcel are working with the Ft. Benning data, I e-mailed a report of my experiences there.

1.6 Received Ft. Benning Lidar Data

Karen Steinmaus at the Pacific Northwest National Laboratory sent us a CD-ROM with Lidar coverage near the MOUT site. We have begun to use these data to evaluate and refine our bald earth and tree height algorithms.

1.7 Supplied ARC/Info Vector Layers of Ft. Benning to Harris

We sent the ARC/Info vector data (which had been supplied to us by NIMA) to Kathleen McKinnon at Harris Corp. (Melbourne, FL).

1.8 Surveying Feature Extraction Methods Used By USGS

I contacted several people working on mapping projects in the USGS in Colorado. I have spoken with them and hope them to supply me with quantified effort required to extract a variety of features and construct thematic maps.

2. ACCOMPLISHMENTS VIS-A-VIS STATEMENT OF WORK

2.1 Refine the BOS architecture

2.2 Survey automated model extraction techniques

1.8

2.3 Develop feature extraction and consistency enforcement algorithms

1.6

2.4 Refine the design of and implement the dynamic database

2.5 Produce, maintain, and distribute data sets and ground truth

1.2, 1.6, and 1.7

2.6 Develop evaluation metrics and perform evaluations

1.1 and 1.6

2.7 Interface to FRE contractors

1.4 and 1.7

2.8 Develop and perform demonstrations

2.9 Transfer technology

2.10 APGD program management

1.3, 1.4, 1.5, weekly conference calls, and this monthly report

Automatic Population of Geospatial Databases
Monthly Report to SRI for December 1997

Bob Wilson
Vexcel Corporation
14 Janurary 1997

1. MAJOR TECHNICAL ACCOMPLISHMENTS

1.1 Receipt of Ft Benning Multisensor Land Cover Classification

With the aid of TMPO, we received Volumes 1 and 11-15 of the Multisensor Land Cover Classification of Ft. Benning prepared by the Pacific Northwest National Laboratory (PNNL) and distributed on CD-ROM. Of the greatest interest to Vexcel are the following files:

mosaic_rc30_final.img	RC-30 basemap
rc30reg.txt	metadata (text)
daed_mosaic.img	Daedalus hyperspectral mosaic
daed_reg.txt	metadata (text)
ben_4002x4002_1m_DEM.img	1 meter DEM
a1m_mak_like_bld.img	buildings
1M_unpaved_roads_class.img	unpaved roads
1M_paved_roads_class.img	paved roads

In addition, the data set includes lots of data already at Vexcel (IFSARE coverage, ARC/INFO layers, etc.)

1.2 Sent IFSARE Processor Documentation to SRI

In response to Marty Fischler's request to understand the "end-to-end" processing of IFSAR data, I was able to locate the "IFSARE Processor Documentation" provided to ERIM by JPL for the IFSARE processor and send a copy to Marty. It was probably more than he was asking for, but some sections should be of use. There is a rigorous definition of the "sch" coordinate system used for IFSARE products. There are block diagrams for SAR preprocessing. Attachment C is a preprint of a paper written by Ernesto Rodriguez, David Imel, and Soren Madsen (all from JPL) on "The Accuracy of Airborne Interferometric SARs." The text of this paper is rather theoretical, however the figures contain useful empirical accuracy results.

1.3 Investigation of Civilian Airborne IFSAR Systems

I was also able to obtain information from web sites concerning the operation of the IFSARE sensor. The sites include www.intermap.ca and www.tec.army.mil.fact_sheet/interfer.html The plane (a Lear 36 jet) typically flies at 41,000 feet and gathers about 100 km**2 of data per minute. IN TEC studies, the RMS height error was found to be 2.45 meters. Intermap has bought the IFSARE system, but DoD has low-cost access to the system for government customers.

I discussed the Sandia Spotlight processor with Dennis Ghiglia (who came to Vexcel with Sandia) and he confirmed that the basic stages of radar processing are similar to those for IFSARE. I obtained some information from www.sandia.gov.RADAR/sar_sub/sar_cap1.html

I investigated GeoSAR, a system under development by the California Department of Conservation, JPL, and Calgis. It is expected to be operational in the year 2000. It will be an interferometric P- and X-band device built by JPL. Calgis will fly the plane. See www.southport.jpl.nasa.gov/html/projects/geosar/geosar.html

A summary of this information was sent on to SRI via e-mail.

1.4 Multisensor Classification

At Vexcel, Ron Xiao has been experimenting with a variety of classification strategies. He has shown that classifications based on a combination of Daedalus multispectral data and IFSARE data are much more accurate--especially for buildings--than either of the single sensor classifications. It is possible to train a classifier (in this case, a neural net) to detect buildings in the MOUT site, but both sensors yield many false positives. For radar, these are structures (such as trunks of dead trees) which participate in a double bounce. For the multispectral data, these are rocky areas which reflect visible/IR in ways similar to the roofs of the buildings. Because of the independence of these error mechanisms, the data can be combined so as to virtually eliminate false positives. At least for the MOUT site, we have obtained the best results by ANDing the results of the separate classifications.

1.5 Provided Data for APGD Demo at SRI

We provided data files for Ft. Benning derived from three different sensors: Daedalus hyperspectral, IFSARE, and Sandia Spotlight IFSAR. The data included LCCs based on IFSARE alone, Daedalus alone, and a combination of the two. It also included the IFSARE volume decorrelation, elevation, bald-earth elevation, and estimated tree height. Classification of the MOUT site was provided for cuing building extraction algorithms.

We initially provided the data on 8 MM tape, but some of the files could not be read at SRI. They were then sent via ftp.

1.6 Discrimination Between Paved and Unpaved Roads

Ron Xiao experimented with discriminating between paved and unpaved roads based on Daedalus and IFSARE data. This proved not to be possible using IFSARE data alone; both dirt and paved roads exhibited a mixture of pixels belonging to the two classes. Based on personal observation, there is very little texture difference between dirt and paved roads at Ft. Benning. The dirt roads are a clay-rich base into which gravel has been pressed by passing vehicles. However, using Daedalus data, it is easy to distinguish clearly between asphalt and red Georgia clay. Note that the shore of the pond and the sides of paved roads are classed as dirt roads.

1.7 Sent More Ft. Benning Data to SRI

The Daedalus mosaic and 1 meter DEM from PNNL were sent on 8 mm tape to SRI. They have not proven useful yet, since they are in ERDAS Imagine format.

1.8 Vexcel's Road Extraction (REX) Algorithm

Work began to improve the performance of REX and incorporate it into Vexcel's IFMAP software package. This work isn't funded by APGD, but may be of interest if the algorithm performs well.

2. ACCOMPLISHMENTS VIS-A-VIS STATEMENT OF WORK

2.1 Refine the BOS architecture

2.2 Survey automated model extraction techniques

2.3 Develop feature extraction and consistency enforcement algorithms

1.4, 1.6, and 1.8

2.4 Refine the design of and implement the dynamic database

2.5 Produce, maintain, and distribute data sets and ground truth

1.1, 1.5, and 1.7

2.6 Develop evaluation metrics and perform evaluations

1.4 and 1.6

2.7 Interface to FRE contractors

2.8 Develop and perform demonstrations

1.5

2.9 Transfer technology

2.10 APGD program management

weekly conference calls and this monthly report

C APGD-IFD Work Schedule, Milestones, and Demo Plans

Our current detailed three-month work plan is focused on meeting our primary first year technical goals and benchmarking our progress in a demonstration at SRI on 16 April 1998.

Primary Technical Goals:

1) Develop and demonstrate the technology necessary to enable an order of magnitude (factor of 10) reduction in the time and effort required to produce a complete road model from aerial/remote-sensed images. In year two, improve road modeling performance by an additional order of magnitude (factor of 100 for the two years). The base-performance reference benchmark is the documented [1] road-model extraction task for the Ft. Benning MOUT site performed by a professional cartographer using a SocetSet work-station; the time required was approximately 270 minutes for 28.5km of linear features, including roads, the runway, and other road-like features.

2) Develop and demonstrate the technology necessary to enable, at least, an order of magnitude (factor of 10) reduction in the time and effort required to model buildings from aerial/remote-sensed images. This is a two year goal. The base performance benchmark is the documented [1] building extraction task for the Ft. Benning MOUT site performed by a professional cartographer using a SocetSet work-station; the time required was approximately 14 minutes for 6 buildings. (It should be noted that it is clearly apparent that there are more than six buildings. Extrapolating from GDE's figures of 0.75 minutes for a simple building and 10.25 minutes for a complex building, we calculate a figure of 70 minutes for the building extraction task.)

3) Develop techniques that can combine and exploit EO, SAR/IFSAR, and multispectral imagery in the above modeling tasks.

4) Provide a framework for robust automated extraction of a full range of cartographic features relevant to building the databases needed to support computer simulation of real and Synthetic Environments, and to support image exploitation.

Critical Components:

1) Algorithms for road and building extraction.

2) Algorithms for ''Super-Resolution'' terrain and 3-D structure

modeling.

3) Algorithms for ‘‘land cover classification’’ (LCC).

4) An algorithm control system to automatically execute the extraction tasks and provide a basis for robust modeling.

5) A technique development and integration platform.

6) Development of highly efficient feature-based editors for spanning the gap between the output of the fully automated extraction techniques and the quality required for the intended application of the models.

7) Registered aerial imagery (EO, SAR, multispectral) for complete high-resolution (0.5-3.0 feet per pixel) coverage of the Ft. Benning test site.

8) Access to conventional state of the art cartographic extraction tools, modeling-performance benchmarks, and productivity statistics.

9) A set of evaluation metrics to quantify performance.

Nominal Allocation of Effort:

1) SRI has full responsibility for the technical competence of all new technology being developed. SRI is the primary source of algorithms for road modeling and for super-resolution terrain and 3-D structure modeling. SRI will provide the technique development and integration platform and the algorithm control system. SRI will propose a set of evaluation metrics to quantify performance. SRI will demonstrate and benchmark progress in the APGD-IFD effort.

2) GDE will provide access to state of the art EO cartographic extraction tools, modeling-performance benchmarks, and productivity statistics. GDE will help in the acquisition and registration of EO imagery and in the production of error models, orthophotos, DEMS, and other derived geometric products. GDE will take initial responsibility for acquiring/developing the building extraction algorithms and evaluating their performance.

3) Vexcel will provide access to state of the art radar and multispectral cartographic extraction tools, modeling-performance benchmarks, and productivity statistics. Vexcel will help in the acquisition and registration of radar and multispectral imagery. Vexcel will take initial responsibility for acquiring/developing the

multispectral and radar-based terrain modeling and LCC extraction algorithms and evaluating their performance.

Current Status and Work Plan:

As an informal summary of our status (January 1998) we believe that we have made sufficient technical progress in road modeling to meet, demonstrate, and benchmark our year one goals, and see no major barrier to attaining the two orders of magnitude speed-up by the end of year two for the types of extraction problems characteristic of the Ft. Benning dataset. We can currently automatically model 90% of the Ft Benning roads (3-D center-line and width) and achieve comparable performance on other sites similar in character to Ft. Benning. This provides one order of magnitude speed-up without any significant use of context. We expect to obtain the second order of magnitude speed-up from a combination of context and specialized high-speed editing. There is still a significant amount of work to be done in integration infrastructure (e.g., putting the road-extraction algorithms under CBACS control to exploit context) and in high resolution attribution of the road model, but no additional technical breakthroughs are required.

Our original plan was to focus on road modeling in the first year in order to develop an end-to-end processing capability and refine the basic system infra-structure. We promised to meet the performance goals for road modeling as described above, but only to demonstrate progress in achieving the two year goal of at least one order of magnitude speed-up in building extraction. Never the less, we still hoped to demonstrate (in the year-one demo) building extraction capability that approaches the two year goal by a combination of automated extraction and specialized high-speed editing. The problem is that because there are such a small number of buildings in the Ft. Benning dataset, the initial (interactive) benchmark time of 14-70 minutes (as noted earlier there is some confusion about the exact figure) could effectively rule out any substantial editing on our part. Further, the buildings are of many different types -- some with unusual shapes that are not included in our library of generic models -- so we can't take advantage of regularity or repetition. At present, the two available algorithms (provided by USC and GDE) can successfully model only 50% of the Ft. Benning buildings by fully automatic processing -- even after successful cuing has been accomplished (i.e., we know the nominal location of all the buildings). We have asked GDE to focus most of their effort on improving the performance of the building extraction algorithms and SRI plans to provide enough additional technical support for the building extraction problem to ensure that our two year goal is satisfied, and hopefully, at least reach the 80% automatic extraction level by 16 April 98.

The use of radar and multispectral imagery will play a critical role in our (final) overall system. Since radar imaging works at night and under cloud cover, it may provide the only imagery available. In this case, we want to get everything we can out of the SAR/IFSAR data. This includes identification of features such as buildings and roads. At present our strategy is to focus on feature extraction from EO imagery, augmented by radar and multispectral data to provide context and independent assessment for confirmation and filtering of derived feature models, and to provide the basic information for material-type attribution. In addition, we have found that radar and multispectral data are highly effective in the cuing task for road and building extraction, and as the primary data source for delineation of rivers, railroad tracks, power-lines, and fences.

In order to effectively use radar data for geometrical modeling tasks, it is necessary to resolve a number of technical issues (we have asked Vexcel to contribute to this task):

a) IFSAR directly and automatically produces an elevation map. However, if there is overlapping optical coverage of the terrain, then DEMs can be generated using stereo matching. When is one source of elevation to be preferred over the other? When compared with ground truth for various sorts of terrain, what are the errors to be expected from each technique? How can we construct a hybrid DEM which is clearly more accurate than one derived from a single modality? What is the best way to (automatically) coregister the DEMS in planimetry and eliminate errors due to height offsets? What is the effect of combining multiple IFSAR DEMs (e.g., the Sandia spotlight data) on accuracy? We need predictive error models for both IFSAR and optical stereo.

(Bob Wilson comments as follows)

IFSARE is processed to a 2.5 meter pixel size. It readily supports ‘‘hasty mapping’’ efforts, having a 10 mile swath width and producing over 100 km**2 of imagery per minute in the air. The data processing required for image formation is non-interactive. A DEM is produced automatically.

On its web pages, TEC reports an RMS elevation error of 2.45 meters for IFSARE. I understand this to be under ideal conditions: non-urban, gently varying terrain. In exceedingly precipitous terrain, it is possible for phase unwrapping algorithms to become confused (by an integer multiple of the wavelength). The leading edges of a precipice may be hidden by layover. Certain areas may lack valid height information because they are in shadow. (But they may identified by viewing geometry.) IFSAR buildings lack crisp edges and vertical foreground faces due to the ‘‘front porch effect.’’

There are many photogrammetric studies of the accuracy of optical stereo, but I have not yet explored this literature. There is Rob Ledner’s use of stereo imaging to produce dense DEMs in urban areas. He performed some tests in Denver, gathering ground truth for GCPs using GPS. The aerial photos were scanned to yield 1 meter pixels. He obtained an RMS height error (again under ideal conditions for the technique, 17 points) of 1.35 meters; the planimetric error had an average of 1.37 meters and RMS of 0.64 meters. He has successfully used his methods in downtown Denver, and obtained much cleaner DEMs than could be expected from IFSAR. In IFSAR DEMS, the buildings would be much ‘‘blobier,’’ less distinct from their neighbors, and have confusing ‘‘front porches.’’

For terrain with distinct features which are not spatially periodic, matching based on high resolution optical images is superior to IFSAR, if the camera models are accurate. Without any ground control, IFSAR would probably be better; in fact, it might be necessary to use the SAR magnitude data to control optical imagery. In the absence of visible features and in the presence of highly periodic features, IFSAR elevations should be more reliable.

TEC (especially Ray Norvelle) has expended a lot of effort quantifying the accuracy of both techniques. I will hunt down some good accuracy analyses of optical stereo matching and IFSAR and provide a report to SRI by 14 February.

Combining DEMs from multiple sources is always challenging, because there are almost always non-trivial height seams when they are simply joined. At Vexcel we have experimented successfully with DEM fusion using wavelet-based representations in the frequency domain. We have several submitted proposals seeking funding to further develop the technique, but it isn’t yet ready for ‘‘prime time.’’ We don’t expect to have an adequate general-purpose solution to this problem until well after the Year 1 Demo.

b) IFSAR provides three channels describing the terrain: magnitude, phase correlation, and elevation. Because of differences in scattering and height, IFSAR facilitates Land Cover Classification (LCC) into a few basic categories. Of course, multispectral images also support LCC. Are there certain classes that are more reliably identified using radar? Can multispectral and radar images be used together to improve LCC? (Vexcel’s recent results for the MOUT site indicate that classification of buildings is very much improved by combining multispectral and IFSAR classification.

This virtually eliminates false positives.)

(Bob Wilson comments as follows)

We have had some good results fusing the Daedalus multispectral data with IFSARE. A summary of our findings is found in the December monthly report I sent on Wednesday (14 January). The virtual elimination of false positives for buildings is quite dramatic and I am sure that this can be incorporated into the Year 1 Demo as part of the cuing procedure for building detection. Further, superior surface material and vegetation classification can be obtained via multi-band and polarimetric radar.

c) Many of the algorithms for extracting wire frame models of buildings from optical imagery benefit from cuing. This is traditionally provided interactively by an operator using a pointing device. If (as Vexcel maintains) the approximate location of buildings can be reliably determined using IFSAR (perhaps augmented by multispectral data, when available), then the cuing step can be replaced by an automatic process based on IFSAR classification. How accurately can buildings be detected? How accurately are they located? IFSAR can provide an approximate building envelope, including footprint and height. How accurate are these measurements? Can an optical building extraction algorithm perform better given these measurements as input constraints?

(Bob Wilson comments as follows)

I think that we have demonstrated the feasibility of this for the MOUT site. What I think that SRI needs is a careful quantitative evaluation of the technique. For the MOUT site we need to show that every building can be detected, with very few false positives (using both Daedalus and IFSARE data). We need to characterize the accuracy with which buildings can be localized in planimetry, and their dimensions and orientation estimated. We plan to provide SRI with a report of these findings by 14 February.

It would be very nice to show that these results hold for other sites as well. Do you know anything about the availability of Daedalus data for any other sites covered by IFSARE? I'm going to check this out next week. (It would be great if there were Daedalus data for Ft. Hood.)

d) Because of the partial penetration of radar through foliage and volumetric scattering (derived from the phase correlation), IFSAR offers advantages over other modalities for detecting trees and estimating tree heights and bald earth elevation. How accurate are these measurements? Can these data yield a measure of visibility through trees which is useful in constructing simulation databases?

(Bob Wilson comments as follows)

This has been the focus of Ron Xiao's research efforts since Christmas. He has shown me some preliminary results, but some of them are still puzzling. I plan to send you an ‘‘in progress’’ status report by 13 March.

e) We already know that certain features (e.g., train tracks, power lines) usually stand out prominently in radar images. Do radar scattering mechanisms present any special advantages in detecting other features (e.g., microterrain features such as ditches, culverts, etc.)?

Train tracks and metal power line supports often show up quite well in SAR/IFSAR. Ron Xiao and I examined the Ft. Benning IFSARE data to hunt for known washes and culverts (described in papers written at the Institute for Defense Analysis). They don't stand out in the radar data. In the publications, they appear as linear features in shaded reliefs rendered from the 1 meter DEM of Ft. Benning. We conjectured that they would probably show up in shaded relief based on the IFSARE DEM as well. We will include our findings in the 13 March status report.

f) What is the most accurate way to coregister SAR images and optical imagery? what is the inherent accuracy of radar images rectified from SCH to UTM projections? Can registration of SAR imagery to optical imagery be improved using GCPs and tie points? What are the most effective algorithms for matching radar to optical imagery? Can GCPs used for absolute orientation of optical imagery be accurately identified in radar imagery?

(Bob Wilson comments as follows)

These are difficult problems for which Vexcel has some partial solutions. I have tried to meet with Jim Curlander (John's brother, who managed the development of a system to facilitate cross-modality image matching), but we haven't connected yet. We will include a discussion of these problems in the 13 March in-progress status report.

Vexcel is committed to the following milestones:

14 February - report on accuracy of DEM formation via IFSARE and optical stereo

14 February - report on accuracy of building detection, localization, and size using IFSARE and Daedalus data for the MOUT site. (It is possible that this may be delayed due to Ron Xiao's illness.)

13 March - in progress status report(s) on IFSARE bald-earth elevation, tree heights, wash detection from shaded relief of IFSAR DEMs, and coregistration of IFSARE with optical imagery.

Note that Vexcel continues to work on radar feature extraction and ''hasty mapping,'' although the funding for this comes entirely from sources other than APGD. The IFMAP software is being prepared for use by TEC under a Phase II SBIR. The system ingests IFSARE data and performs LCC, bald-earth extraction, tree height estimation, etc. Modules have been added for drainage/hydrology and power line extraction and delineation. REX is currently being incorporated into IFMAP and I am encouraging the engineer working on this to carefully evaluate the performance of the algorithm.

THE PLAN FOR THE YEAR-ONE DEMONSTRATION

This description documents our plans for the overall flow of data and control and requirements for the April 16 demonstration. It is divided into three sections: data acquisition and registration, feature extraction and attribution, visualization.

1 Obtain & control imagery covering Ft. Benning/MOUT

1.1 Description of Dataset

The dataset includes:

- 15cm GSD panchromatic images (44)
- Level 2 DTED (30m GSD)
- 15cm GSD Orthomosaic
- 2.5m GSD ERIM IFSARE (magnitude, correlation, elevation)
- 40cm GSD SANDIA Spotlight IFSAR of MOUT area

Land Cover Classifications derived from:

- DAEDALUS
- IFSARE
- SANDIA Spotlight IFSAR
- DAEDALUS and IFSARE

Database Generation Report

1.2 Registration

For the panchromatic imagery the registration is a well understood process. The only open issue is the availability of covariance estimates for the camera parameters, due to the fact that SocetSet does not currently produce this data. Still, informal estimates of relative accuracy of point triangulation can be carried out.

For RADAR and MS the issue of registration is somewhat more complicated because we have been supplied with products (as opposed to raw data) that have already been rectified to UTM coordinates and the metadata supplied does not contain any estimates of the accuracy with which this was carried out. We can, however, assume that the UTM transformations are correct and carry out a conventional ‘‘single image’’ registration against ground control points identified and triangulated in the panchromatic imagery. Any error in the sensor to UTM transformation will be represented by the residuals in the parameter fitting process.

This, combined with the very large difference in GSD between the panchromatic and radar and MS coverage (over 10:1), limits the utility of these other sources to providing constraints for extraction processes operating on the panchromatic imagery.

At this point SRI is undertaking further investigation of the registration issues between panchromatic and RADAR and MS imagery. Vexcel is looking at the error modeling of IFSARE and Sandia Spotlight coverage. They also have another project for comparisons of EO and Radar derived terrain data. GDE is currently investigating the use of other software to derive covariance estimates for the panchromatic imagery. As a backup, SRI can redo the block adjustment with the photogrammetry package we have developed in RCDE, however this would result in another set of camera parameters as well.

1.3 Land Cover Classification and visibility estimates

Both the IFSARE and MS coverage of Ft. Benning has been run though a number of classifiers, to obtain Land Cover Classifications. These are used by CBACS to establish context and therefor choose algorithms and set parameters for the feature extraction operations. The principle classes we are interested in are: urban or man-made, water, forest, open terrain. Vexcel is also currently investigating the use of the IFSARE data to provide visibility estimates based on the degree of volume decorrelation.

1.4 DEM construction

Digital elevation models are available as a standard NIMA product or can be produced by SocetSet. In the case of the Ft. Benning dataset, a DEM was produced by GDE using SocetSet from the panchromatic coverage.

1.5 Orthomosaic construction

The DEM produced in the previous step was used to construct a full-resolution orthomosaic of the study area. The standard tools available in SocetSet were use for this.

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2 Feature Extraction

2.1 Construct 3-D attributed road-network model

2.1.1 Low Resolution road modeling

This will be carried out using Fischler's linear delineation system, operating primarily on the panchromatic orthomosaic. This produces cues for the higher resolution extraction process and establishes the initial topology of the road network.

Current work involves merging results from multiple resolution processing and roads with differing photometry. In addition the LD system needs to be put under CBACS control so that it can use the Land Cover Classification results for local parameter adjustment.

2.1.2 Road connectivity and topology extraction

The work needed for the initial connectivity and topology extraction is complete. A separate API needs to be established for this module so that it can be used by other parts of the system, so that topology can be recomputed after, for example, the editing stage.

2.1.3 3-D centerline refinement

Initial work in this area is complete and was presented at the Fall APGD workshop. The decision criteria used needs to be formalized and automated.

2.1.4 High-resolution analysis and refinement

2.1.2.1 Model-Based Optimization

The first stage of this process is based on an adaptation of the 3-D multi-image model-based optimization technology developed under SRI's RADIUS BAA effort. Additional work is needed to handle partial road visibility and cases where a single road extends across a number of images, and to bring the operation of the MBO subsystem fully under CBACS control allowing the use of different parameters for paved roads, unpaved roads, and paths.

2.1.2.2 Evaluation and confirmation

Evaluation and confirmation of the road centerline and widths will be accomplished by local application of SRI multi-image 3-D Deformable Mesh technology. This allows us to extract a very high resolution 3-D model of the each road and surrounding terrain. This geometry will be used to verify that the extracted road is actually ‘‘driveable,’’ using criteria such as cross-sectional slope, gradient, curvature. The selection of these criteria will be controlled by the type of road and surrounding terrain as determined by the Land Cover Classification. This processing can also potentially identify overhanging trees and trigger an automated merging process.

The remaining tasks in this area are to automate the application of the meshes and to formalize the 3-D centerline placement decision criteria.

2.1.2.3 Attribution

Road surface material will be determined through the RADAR and MS derived Land Cover Classification.

2.2 Buildings

The current approach to modeling buildings relies on technology being developed at GDE and USC. (During the second year of the project, SRI will concentrate on buildings and develop some techniques of our own.) GDE’s algorithm requires cuing in the form of a single point placed within the footprint of the building. USC’s algorithm does not require this, but can take advantage of this information. The 40cm Sandia Spotlight IFSAR will be used for automatic cuing. Vexcel is currently working on deriving the cuing point automatically from IFSAR and DEM information.

USC’s algorithm runs within the RCDE, so the results can be directly inserted in to the BOS system’s persistent store. GDE’s algorithm runs in SocetSet and can produce output in AutoCAD DXF format in UTM coordinates. We are currently writing a DXF reader for RCDE to import these models. In preliminary experiments, we have transfered cultural features from SocetSet to RCDE without any problems.

3 Visualization of Results

Results from the feature extraction will be displayed in three ways:

A fly-along viewer which will constrain RCDE's roam operation to a particular linear feature.
Static IPT generated with facilities in RCDE.
In a VRML viewer, using RCDE's VRML translator

The fly-along view is currently being developed for the demonstration. RCDE's VRML translator is being enhanced under another project to generate VRML2 and multiple levels of detail.

We are also pursuing the generation of databases that can be used with standard Synthetic Environments tools, but do not anticipate that this will be ready for the April demonstration.

4 Evaluation of Results

The following criteria are intended to evaluate the automatic modeling performance of the algorithms under consideration. A separate issue is the time needed to upgrade the automatically produced results to the standards required for any given applications. This in turn requires the availability of feature-specific editors that are currently under development.

4.1 Roads

The reference information for roads will be the model created by GDE [1]. This model includes both roads and road-like features, some of which are speculative. We will only include the subset of roads that are clearly recognized at such for scoring purposes.

The metrics we will apply will include:

- percentage of roads in the reference model that were correctly delineated by our algorithm
- percentage of roads delineated by our algorithm that are in agreement with the reference model
- Topological accuracy -- this will examine the major intersection (i.e. we will ignore intersections associated with driveway, spurs, etc.) and determine whether they are properly located and whether the connectivity for the incident roads agrees with the reference
- The two main attributes of concern, width and road type (i.e., paved vs. unpaved) evaluated. Other attributes that are extracted will not be given a quantitative evaluation in this benchmark, because of lack of reference data for this purpose. These include, across and along-road profiles.

4.2 Buildings

The reference information for buildings will be the model created by GDE [1]. The building extraction paradigm that we are following involves a cuing step that make use of IFSAR elevation and material classification results. The accuracy of the cuing will be scored separately based on the percentage of buildings in the reference data that were correctly cued and the percentage of cues that were correct with respect to the reference data. A give cue will considered correct if the cue point lies inside the building footprint.

The building extraction algorithms will be scored relative to the cuing information (which may be correct or incorrect) and stated competence to deal with different building geometries. For example the available algorithms are restricted to buildings with polyhedral footprints where the vertical surfaces meet at right angles, and hence will not be evaluated on curved structures.

A building model be considered to be correct if the extracted footprint geometry matches that of the reference data in terms of the number of sides and correct placement of the vertices. The roof type will be judged correct or incorrect based on the determination of whether the roof is flat vs. pitched, peaked, etc. Roof detail such as dormers and parapets are beyond the capabilities of the algorithms under consideration and will not be scored.

No score will assigned for buildings geometries that differ from those claimed to be covered by the extraction algorithm.

REFERENCES

[1] Ft. Benning GA. McKenna MOUT Database Generation Final Report, GDE Systems, San Diego. Available from via the URL http://www.ai.sri.com/~apgd/vl/datasets/Benning/db-report/

D Reply to questions (2/24/98)

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**Demonstration plan and associated metrics.

Several aspect of the demo plan need clarification and elaboration. Perhaps
the best way to express these points is in the form of questions, whose
answers will help George and Michele understand what you plan to show in
April:

1. What steps in the imagery-to-end product database process will
demonstrated live? Which steps, if any, will be pre-processed (canned)
and/or excluded from the construction scenario?

=================================================================
1a)  The precomputed dataset to be used in the demo will include:

         15cm GSD panchromatic images (44)
         Level 2 DTED (30m GSD)
         15cm GSD Orthomosaic
         2.5m GSD ERIM IFSARE (magnitude, correlation, elevation)
         40cm GSD SANDIA Spotlight IFSAR of MOUT area

         Land Cover Classifications derived from:
                DAEDALUS
                IFSARE
                SANDIA Spotlight IFSAR
                DAEDALUS and IFSARE

1b)  The entire road-modeling task (both automated extraction and human
editing will be demonstrated live.

1c) The building-modeling task has an automated initialization/cueing
step that currently employs Vexcel software.  Depending on the cost
of the commercial licenses required (from PCI), the automated cueing
computation will either be demonstrated live at SRI or precomputed at
Vexcel.

1d) We expect to be able to run the USC/GDE software for
building-modeling live at SRI; this will include any required human
initialization or editing.
====================================================================


2. What portion of the BOS infrastructure planned for implementation in the
two-year base period will be included in the demonstration and how?
Conversely, what parts of the planned infrastructure will be deferred to
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later demos? For example, to what degree will CBACS be used to select algorithms and/or set parameters for road and building extraction? What import/export facilities of the BOS will be exercised? Deferred? What portion of the planned editor and other GUI, will not be included in the April demo?

==

2a) BOS will control the road-modeling task -- algorithm selection/sequencing and parameter selection. It will use context computed from the Vexcel provided Land Cover Classification data (imported or computed live from the IFSAR and DAEDALUS data), and the imagery description information (e.g., GSD).

2b) We expect that CBACS control of the building-modeling task will be deferred to a later demonstration.

2c) The editing required for the building and road modeling tasks will be demonstrated live at the April demo. More advanced versions of the editors will be produced for later demonstrations.

==

3. To what extent will the explicit use of context be demonstrated, e.g., engineering domain knowledge (expected grades, intersection constraints), geo-specific knowledge (roadmaps), world activities models (anticipated vehicle occlusions on roads), and/or site history models (last year's linear features model prior to known grading)?

===

3a) Some of the algorithms have built-in constraints based on assumptions about nature of the images, the sensors, and the context of the scenes they are to be applied to; others have parameters that must be set based on knowledge of imaging and scene context. This information is made explicit in the formalized "wrapper" provided by the algorithm designer that is required to describe the algorithm to CBACS. At present, we use the broad categories of rural, suburban/town, and urban/city to select algorithms for road delineation. We have focused on algorithms for fully automated road-extraction in rural terrain since this was required for the Ft. Benning site -- we are currently developing the extensions necessary for fully automated suburban/town road and STREET extraction; these algorithms will be available for later demonstrations.

3b) Some constraints on road construction practice (e.g., curvature, width, and surface material) are built into special filters that are components of the road modeling algorithms; other constraints (e.g., cross and along-road elevation profiles) are explicitly asserted and employed by CBACS to filter out errors in an already compiled road model. We are currently focusing on the problems of "cold-start" in

the road and building-modeling tasks, but have the have the machinery necessary to take advantage of a priori knowledge of the likely location of these features.
==

4. Will road and/or building extraction algorithms be cued by Vexcel's LCC results?

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YES. See 1c and 3.
===

5. Will GDE and Vexcel aspects of the demo be performed on-site, remotely, or pre-processed?

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Wherever feasible, we will demonstrate GDE and Vexcel algorithms and results computed live at SRI. We expect that any required manual intervention or editing will be done at live at SRI. See 1b, 1c, and 1d.
==

6. How do you plan to measure the degree to which you have met the goal of a 10-fold reduction in time to generate a complete road model? I assume "time" means elapsed clock time; correct? When does the clock start and what machine and human steps in the process will and will not be included in the calculation of elapsed time?

==
6a) Yes, "time" means elapsed clock time. A stop watch will be used to measure the amount of human intervention and editing. The clock runs whenever the human is involved in an interactive exchange with the computer based on a view of the imagery or the constructed model. Machine-time itself is not is not measured if the human is not interacting with the machine.
==

7. How will geometric accuracy of extracted roads be measured against the reference model? What is a "road" in the statement "percentage of roads in the reference model that were correctly delineated by our algorithm"?

==
Geometric accuracy will be measured by comparing the 2-D or 3-D deviation between the computed road model and the reference model. If this deviation is less than some specified amount (possibly related to the GSD of the imagery, but nominally within one road-width of the reference road-centerline) the computed model will be considered correct. Percentages are ratios of distances along the road

center-line.
==

8. I understand that building extraction results will be measured at the system (end product) level rather than the algorithm level as the plan states. What measurements will be provided comparing the buildings in the end product against the reference model?

==
A building model be considered to be correct if the extracted footprint geometry matches that of the reference data in terms of the number of sides and correct placement of the vertices. The roof type will be judged correct or incorrect based on the determination of whether the roof is flat vs. pitched, peaked, etc. Roof detail such as dormers and parapets are beyond the capabilities of the algorithms under consideration and will not be scored.
===

9. Will a geographic comparison between the end product and the chosen reference model be displayed?

===
YES. Results from the feature extraction will be displayed in three ways:

A fly-along viewer which will constrain RCDE's roam operation to a particular linear feature.
Static IPT generated with facilities in RCDE.
In a VRML viewer, using RCDE's VRML translator

The fly-along view is currently being developed for the demonstration. RCDE's VRML translator is being enhanced under another project to generate VRML2 and multiple levels of detail.

We are also pursuing the generation of databases that can be used with standard Synthetic Environments tools, but do not anticipate that this will be ready for the April demonstration.
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10. Has the chosen reference model been validated? If so, how?

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The chosen reference model, for both roads and buildings is the one constructed by a professional cartographer at GDE using Socket-Set

(REF: Ft. Benning GA. McKenna MOUT Database Generation Final Report, GDE Systems, San Diego. Available from via the URL http://www.ai.sri.com/~apgd/vl/datasets/Benning/db-report/)

We will manually inspect the models and compare them to known ground truth if they appear to be unreasonable or incorrect.
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*Planned technical activities.

Brief responses on each of the following would be helpful.

1. The stated year two goal is "two orders of magnitude speed up for the types of problems characteristic of the Ft. Benning dataset." This is at odds with George's desire for improved extraction results with sites of increasing complexity.

=> We expect to obtain 1-2 orders of magnitude speed-up for more complex rural and suburban type scenes.

2. The LCC effort by Vexcel appears to be addressing traditional land use classes which may or may not be the classes that are important to cueing of extraction algorithms.

=> The LCC effort by Vexcel being done for the APGD effort IS strictly focused on the classes that are important to cueing of extraction algorithms.

3. The term "super-resolution terrain" is not defined.

=> We mean the extraction of 3-D models form multiple images that exceeds the accuracy possible from two-image stereo.

4. The APGD relevance of the discussion on creating high spatial density DEMs is unclear, particularly comparing IFSARE vs. overlapping optical coverage.

=> We need the high density/resolution (in very localized regions) for verification and cueing tasks. We also need to know how IFSAR and EO can be combined for this purpose when both are available.

5. The document states Vexcel will produce a report on building extraction using IFSARE and Daedalus, but its planned content is unclear. Will it address the quality of the DEM needed to do this, how a suitable quality DEM would used in the building extraction process, and how such a process might be combined with more traditional techniques for building extraction in an IFD demo?

=> Our primary concern here is be able to predict the validity of the cueing results to be used for building extraction.

6. One of Vexcel's paragraphs mentions some non-APGD work (hasty mapping, IFMAP software) without a clear reference to its applicability to APGD.

=> Since we can get the IFMAP software at no cost to APGD, and since it gives us an extra "opinion" on some of the features we want to extract or to use for context, we are happy to accept the gift.

7. Vexcel uses the term "visibility estimates" without elaboration.

=> We are interested in estimating how far one can "see" (e.g., through trees adjacent to a modeled road) in constructing a model to be used for SE applications.

8. In general, I had difficulty with the section of the plan beginning with "In order to effectively use radar data for geometrical modeling tasks, it is necessary to resolve a number of technical issues (we have asked Vexcel to contribute to this task)." It reads more like an FRE tech note than an IFD plan. The SRI-Vexcel dialog, with several specific technical questions and related discussion, provides useful insight on status and technical approach, but lacks a clear IFD planning dimension. It is not clear whether or when the results of the stated Vexcel technical tasks are expected to yield IFD demonstrable results.

=> We have described the role radar and multispectral analysis will play in our overall system -- cueing, context, and replacement for EO at night or in bad weather. Vexcel is responsible for providing this technology.
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