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An Integrated Feasibility Demonstration for Automatic Population of Geospatial Databases

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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 reporting 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]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.

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)

We have developed and continue to enhance an end-to-end example (raw data to visualization) of linear delineation for railroads. This is being used as an initial check on the suitability of the architecture to acomplish the BOS modeling and visulation goals. At this point in time no modification to the architecture is needed.

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 extracting algorithms. (Q3–6)

The internals of the inference engine and context representation system has been reimplemented taking advantage of experience gained from the HUB system in RADIUS. We are calling this technique *Object-Oriented Context Manipulation* to contrast it with the old HUB architecture which was based on a flat rule set that represented context.

- Lessons from the HUB:
  1. One large rule set gets bulky, hard to maintain, hard to locate rules.
  2. Name clashes can occur.
  3. Rule sets can become inconsistent.
  4. No modularity – no notion of separate contexts for different feature types.
  5. Algorithm specification was primitive – only a limited set of parameters could be selected or changed.
- BOS uses object-oriented context manipulation. Context is represented hierarchically.
  1. context objects contain externally visible variables, internal rules.
  2. context "variables" provide I/O – visible state.
  3. rules are encapsulated.
  4. Setting certain variables invokes rules that dictate the settings of remaining variables.
  5. Ensures that a suitably instantiated "context" always exists for the current problem.
- Hierarchy:
  1. We can break the rule sets down into modular pieces.
  2. Common "primitive" rules can sit near the top (e.g., generally useful predicates such as member and append, or generic site/image/feature predicates).
  3. Derived contexts inherit rules from parent contexts.

4. Modifications of parents propagate to derived contexts.
5. Modular design allows different rule sets to be constructed for different feature types (feature extraction managers).

- Future directions:

1. Integrating other algorithms into the linear feature extraction subsystem.
2. Defining FEMs for other feature types.
3. Prototyping CBACS:
   - FEM specifies task
   - CBACS generates one or more choices with idealized parameter settings.
   - CBACS must keep track of this and prior context-parameter pairings.
   - CBACS will need to evaluate and remember algorithm performance.
   - Needs to be able to generate a dense sampling of context space – synthetic images?

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)

A skeletal implementation of the FEM for LOCs has been completed. It will be demoed at the IPR. We are currently investigating the modularity and role of the FEMs to see if a higher level control corresponding to domain experts is needed. Work on feature-specific editors is starting.

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)

Initial SAR/IFSAR survey is complete. The bibliography is available via the URL `http://www.vexcel.com/proj/apgd/sarbib.html`. LOC and building extraction surveys are being completed and will be available via the Virtual Lab.

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+)

Our primary initial task in algorithm development is (1) to select baseline algorithms for linear features (primarily roads), buildings, and ground cover classification, (2) to port the selected algorithms to the RCDE for evaluation and testing, and (3) to set up a benchmarking facility (or procedures) so that other algorithms

developed in the APGD community can be evaluated and, if appropriate, incorporated in our actual or conceptual BOS system.

Our effort to select a baseline linear delineation (LD) system as part of the BOS architecture, and to port it to the RCDE system for evaluation and testing is almost complete. We have selected components from the SRI low-resolution generic-LD-research-system (developed on LISP machines) and reimplemented the code as needed for RCDE compatibility. Some errors were introduced in the conversion process, and these are being eliminated as we encounter them. Some special modifications and additions were needed to specialize the system to deal with roads, and these are being inserted. Our current implementation was deemed good enough, at present, to demonstrate state-of-the-art (or better) performance for low-resolution fully automated road detection, and we have a version running on our virtual lab which should be debugged within the next few weeks. We expect to have an initial benchmarking facility and baseline algorithm for automated low-resolution road extraction running in our virtual lab by the end of August.

Further work will involve putting the algorithm under CBACS supervision to exploit contextual information; adding additional road extraction components to deal with high resolution imagery; and putting in the machinery to deal with SAR and other sensor modalities.

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 3D coordinates. Implement photogrammetrically rigorous error analysis and propagation facilities in the RCDE.* (Q1–4)

As noted in last month's report, our proposed approach to sensor adjustment and error propagation is being studied by GDE for use in their Universal Sensor Model work. We are currently waiting for feedback on this from GDE and other members of the community.

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)

The railroad extraction scenario/demo is being used to test the initial implementation of the persistent store for linear features. The representation for geometry and topology is adequate. Further work on attribution is needed. Specifically the ability to assign attributes, confidence figures, and so forth to individual (and arbitrary) segments of a road is needed.

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)

Imagery and other data is being assembled for the Ft. Benning data set. The following is currently available:

- 33 panchromatic aerial survey images
- 2.5m GSD SAR/IFSAR coverage mosaicked and rectified to UTM
- 0.4m GSD SAR/IFSAR coverage in SCH format
- control data survey compiled by DMA in 9/95
- RCDE "ground data" models the the MOUT site and surrounding LOCs.
- 1m grid-post digital terrain model

We would also like to obtain the DAEDALUS MS collection for Ft. Benning.

This dataset will be assembled by GDE and Vexcel for distribution in late October. The formats will be:

- raw 8-bit images with TEC headers
- RCDE "site glue" format
- ASCII 200EAA format ("RPC") for camera parameters

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)

An annotated pixel classification image of the fhn717-719 area of Ft. Hood has been constructed. This labels pixels as roads, proto-roads, etc., as well as indicating the surface material. This will be used to evaluate automatic extraction algorithms and will be made available via the Virtual Lab.

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)

We have completed the first draft of evaluation metrics and procedures for linear features and buildings. These will be briefed at the upcoming IPR and made available via the Virtual Lab shortly thereafter.

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 initial page for the Virtual Lab has been created. The URL is `http://www.ai.sri.com/~apgd/vl`. It provides a summary of data sets currently available from SRI for use by the APGD contractors and access to relevant documents. The SRI low-resolution linear delineation system is available for experimental evaluation via the Remote Execution Facility.

Currently we are working on enhancing the Virtual Lab. The goal is to improve the user interface by providing the capability for dynamic image manipulation, e.g., image processing, coordinate selections, etc.. These will be performed in a pre-processing stage before executing a remote algorithm. For example, before running the Linear Delineation algorithm the user may want to first run an image convolution followed by a scale change. Primary activities to date have been in assembling the necessary CGI scripting mechanisms and Web-based Java language for this process.

Work on a benchmarking facility for linear delineation is underway. This will make use of a "ground truth" reference image to test algorithms for accuracy in extraction of geometry and topology.

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 with USC and UMass for technology transfer and evaluation of their building extraction algorithms. GDE is scheduled to visit USC on 8/11 for a TEM. Initial work will be to transfer USC's monoscopic algorithm and to work out data transfer and format issues. Work on the stereo algorithm will commence when it is available from USC.

The radar short course was scheduled for 18-19 August at Vexcel's new offices. Vexcel constructed a program for the course and arranged for the participation of two guest speakers: Paul Eichel (Sandia) and Jakob van Zyl (JPL). Announcements were broadcast via e-mail. A registration packet was prepared and sent out via USPS Mail to people who had expressed an interest in the course.

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)

An initial FEM/CBACS demo has been developed using the railroad extraction scenario. This will be presented at the upcoming IPR.

Our continuing work in this area is to develop a scenario and for Ft. Benning/McKenna MOUT demonstration.

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)

Work continues (in cooperation with GDE) on establishing a data path between RCDE and SOCET Set. Initial data exchange experiments between SRI and Vexcel have been carried out successfully.

Work is also on going with Vexcel to estabilsh a data path between RCDE and IFMAP. In addition, a copy of RCDE has been installed at Vexcel.

3 Meetings and Reports

The next scheduled meeting is the IPR on 14 August.

A GDE/USC TEM is scheduled for 8/11. An SRI/Vexcel TEM is scheduled for 8/20. 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 August 10, 1997

SUMMARY: Work during this period has emphasized the selection of baseline building extraction algorithms, definition of a benchmarking procedure and preparation of test data sets.

DETAILED WORK DESCRIPTION (BY SOW ITEM):

1. ARCHITECTURE REFINEMENT: No activity

2. ALGORITHM SURVEY: We are completing a bibliography of building extraction techniques to document our survey.

3. ALGORITHM DEVELOPMENT: Although the USC building algorithm has been tentatively selected as the baseline, we are devoting some effort to extending and solidifying our in- house algorithms for comparison with the baseline and to fill any gaps that may emerge during evaluation and benchmarking.

4. MULTI-SENSOR REGISTRATION: No activity

5. DYNAMIC DATABASE: No activity

6. DATASET PRODUCTION & DISTRIBUTION: The test data sets have been selected from the Fort Benning imagery, and we have begun generating terrain and features using current manual procedures to act as ‘‘ground truth’’. Those data sets will be made available as soon as they are completed.

7. EVALUATIONS: Our building extraction algorithm benchmarking procedure has been completed, documented, and reviewed by the prime. We plan one final technical meeting with the team before presenting it at the upcoming IPR.

8. INTERFACE TO FRE CONTRACTORS: We have scheduled a visit to USC on August 11 to begin the transfer of their building extraction algorithm to our lab. We will begin by transferring the monoscopic algorithm and using it to work out data transfer and format issues. The stereo algorithm, which has tentatively been selected as our baseline, should be available within the next few weeks. Our discussions with UMass have been positive, but lack of funding on their part will prevent transfer of their Ascender system to us at present.

9. DEMONSTRATION SCENARIOS: No activity

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 Report

Automatic Population of Geospatial Databases
Monthly Report to SRI for July

Bob Wilson
Vexcel Corporation
21 August 1997

1. MAJOR TECHNICAL ACCOMPLISHMENTS

1.1 Processing Aerial Photography of Ft. Hood to Create "Truth" Dataset for IFSAR Classification and Feature Extraction (in progress)

Despite trying several different photogrammetric techniques, we have been frustrated by the poor quality of the mosaics we have obtained. The originally supplied exterior orientations appear not to be accurate enough to prevent large pixel shifts along the seams of the mosaic. We are continuing to work with Aaron Heller on this problem.

1.2 Organization of SAR/IFSAR Tutorial (in progress)

The short course was scheduled for 18-19 August at Vexcel's new offices. We constructed a program for the course and arranged for the participation of two guest speakers: Paul Eichel (Sandia) and Jakob van Zyl (JPL). Announcements were broadcast via e-mail. A registration packet was prepared and sent out via snail-mail to people who had expressed an interest in the course.

1.3 Documentation of Vexcel's IFSAR Terrain Classification Software

Vexcel has developed a package called IFMAP to perform terrain classification and bald earth extraction for IFSARE data. The developer of this package wrote a description of this software, including requirements, parameters, algorithm descriptions, etc. A preliminary draft of this documentation was e-mailed to SRI in preparation for the IPR (14 August).

1.4 Enhanced Web Sites

SRI told us about the addition of on-line road delineation capability and we tried it out. Wanting to exercise it on some IFSAR imagery and provide access to such imagery to SRI, we added TIFF images of the Ft. Benning MOUT site to our APGD web site. The initial set of images were 1K by 1K coregistered feature layers including magnitude, correlation, elevation, correlation gradient, elevation gradient, RMS magnitude, volume decorrelation, land cover classification, and bald earth elevation. Initial experiments indicated that these data posed a difficult challenge for the road finder.

1.5 Obtaining Ground Truth for Ft. Benning MOUT Site

Ernie Reith (NIMA) has provided us with ground truth for this site. It includes a bald earth DEM and an ground cover classification consisting of Arcinfo vector layers. This will be used at Vexcel to evaluate the IFMAP software. After analyzing these data we plan to make them available

via the web.

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

There is plenty of this work going on at Vexcel, but it has not yet received support under the APGD contract.

2.4 Refine the design of and implement the dynamic database

2.5 Produce, maintain, and distribute datasets and ground truth

1.1, 1.4, and 1.5

2.6 Develop evaluation metrics and perform evaluations

2.7 Interface to FRE contractors

1.2

2.8 Develop and perform demonstrations

2.9 Transfer technology

2.10 APGD program management

weekly conference calls and this monthly report

No travel for APGD took place in the month of July. Next month labor charges will show a spurt due to the SAR/IFSAR tutorial.