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Artificial Intelligence Center

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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.

[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.

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)

We are currently in the process of instantiating the 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 Land Cover Classifier; will select and instantiate the 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)

We are simultaneously enhancing the infrastructure that is integrates CBACS into the overall BOS architecture and are currently focusing on the specific specifications for the "algorithm wrappers" that CBACS uses to make its decisions.

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)

The feature extraction manager has a number of templates (a general scheme for the processing) for the different tasks. Its job is to select the appropriate template and initiate it for the specific task under consideration. We are using the first year's demo as a prototype for further refining the role of the FEMs.

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+)

We have begun work on a high-resolution technique for road centerline refinement and attribution of lane structure and road width. A technical report on this work including examples is being prepared. A summary of this technique is in Appendix C of this report.

Evaluation of the low-resolution linear delineation subsystem is proceeding at GDE and SRI. Our main task is now to integrate the low- and high-resolution algorithms that we have assembled to produce the 3-D road model that is the final output of this process.

We expect to complete the work on this part of the effort by the middle of February.

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)

If a problem arises in our attempt to integrate two different sensor modalities this could provide direction for additional refinement of the registration process. However, the facilities in place are adequate for our current needs.

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)

We have built machinery for caching and keeping track of the processing history of our algorithmic activity both for purposes of efficiency and for keeping an audit trail of how the current results were obtained and how they differ previous results.

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 It will be distributed in early November and will 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
- DMA DTED
- Dædalus MS collection

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 parts of 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 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)

Evaluation metrics for linear delineation have been formulated. A draft report on evaluation was completed and sent to the program monitors and managers for review. A revised version will be completed by 15 December. A benchmarking facility based on these will be available on the Virtual Lab at that time.

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 algorithm bibliographies have been added to the virtual lab. The SRI low-resolution linear delineation system continues available for experimental evaluation via the Remote Execution Facility. An update version which is suitable for SAR will go on-line by 8 December. A first implementation of a benchmarking facility for linear delineation has been completed and will be available by 15 December.

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

- 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.

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 and preparing the Ft. Benning dataset.

Vexcel is preparing the MS and SAR components of the Ft. Benning dataset.

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)

This will be discussed at the November workshop.

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 on establishing a data path between RCDE and SOCET Set and Vexcel systems.

The recently completed linear delineation system will be supplied to any RCDE user for evaluation.

3 Meetings and Reports

The APGD workshop is scheduled for 11/19 & 11/20. In addition to SRI, Vexcel and GDE will be attending.

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
October 10, 1997

SUMMARY

Work during this period has 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 preparing a summary of the state of the art in automated building extraction, as revealed by the papers in our bibliography.

3. ALGORITHM DEVELOPMENT: Work continued on confidence measure development.

4. MULTI-SENSOR REGISTRATION: No activity

5. DYNAMIC DATABASE: No activity

6. DATASET PRODUCTION & DISTRIBUTION: The Fort Benning database has been assembled and sent to the FREs. The data tapes contained the images themselves, the associated support data, digital terrain data, and an ortho-mosaic.

7. EVALUATIONS: Our procedure for algorithm evaluation, based on a cost of editing metric has been defined and documented. Manual extraction of the buildings in our selected tests chips from Fort Hood has been completed. Evaluation of the USC stereo algorithm and of GDEs radiometric algorithm has begun. A test data set will be made available to the community to permit self-testing and encourage the submission of superior algorithms to be incorporated into the 1998 demo. The data set will contain a representative subset of the test data, together with a description of our evaluation procedure, manual extraction results, and an indication of current baseline performance.

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

9. DEMONSTRATION SCENARIOS: Preliminary investigation of available

visualization techniques has been done in support of the end-to-end demo planned for next spring.

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 October

Bob Wilson
Vexcel Corporation
10 November 1997

1. MAJOR TECHNICAL ACCOMPLISHMENTS

1.1 Enhancement of IFMAP Software to Compute Confusion Matrices

A popular way to compare two different classifications (e.g., and experimental LUC vs. a reference dataset) is via a confusion matrix. The ability to calculate such matrices has been added to the IFMAP package (which operates in the context of PCI's software) in order to support evaluation of its algorithms.

1.2 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 LUC 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.

1.3 Supplied Ft. Benning ARC/INFO Data to SRI

The ARC/INFO data was sent to SRI. It includes a road layer, which may be useful in evaluation low-resolution road delineation algorithms.

1.4 Supplied TOPSAR Image of Antioch, CA, to SRI

At the request of NIMA, Vexcel has used a TOPSAR image of Antioch, CA, to evaluate the performance of REX (Vexcel's Road EXtraction program). This SAR image presents many formidable challenges for road extraction. We supplied this image (and associated "ground truth" in the form of a USGS DLG road layer) to SRI for them to exercise and hone their software.

1.5 Refine APGD Evaluation Strategy

An outline concerning "Evaluation of Radar-Based Land Use Classification (LUC)" and "Evaluation of Radar-Based Elevation Models and Building Heights" was sent to SRI for incorporation into our APGD Evaluation Strategy.

1.6 IFSAR Land Use Classification via a Neural Network

We have begun to prototype an IFMAP-like capability based on neural networks, rather than on knowledge-based models. Its performance will be quantitatively compared with IFMAP.

2. ACCOMPLISHMENTS VIS-A-VIS STATEMENT OF WORK

2.1 Refine the BOS architecture

2.2 Survey automated model extraction techniques
1.5

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 datasets and ground truth
1.3 and 1.4

2.6 Develop evaluation metrics and perform evaluations
1.1, 1.2, and 1.5

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

C Road Center and Width Determination

- **Objective:** Given an coarse estimate of the road centerline, estimate the location and width of each road lane to approximately one pixel.
- **Assumed inputs:**
  - Estimate of road centerline. Positional accuracy may be in error by several multiples of the road width. Directional accuracy needs to be within 5-10 degrees.
  - Image with camera model containing the the road at a ground sample distance of approximately 1.5 feet per pixel or better.
- **Processing Steps:**
  - **Resample Image:** Resample the image into a road centered image $I(x,y)$ whose vertical axis in in the direction on the road, and whose horizontal axis is in the cross road direction. $I(x,y)$ has dimensions N_x and N_y.
  - **Detect Remove Vehicle Sized Anomalies:**
    * Compute the local image operator:

$$anom(x,y) = min(var_x(I,x,y,w_x), var_y(I,x,y,w_y))$$

      where var_x is horizontal intensity variance centered at x,y with width w_x, and var_y is a vertical variance centered as x,y with height w_y. The parameters w_x and w_y are chosen to respond best to expected vehicle dimensions. Values of w_x = 10 feet and w_y = 16 feet seem to work well. Elongation of vehicle appearance due to shadows must also be considered.
    * Compute the anomaly removed image $I'(x,y)$:

$$I'(x,y) = \begin{cases} 0 & \text{if } anom(x,y) > \alpha \\ I(x,y) & \text{otherwise} \end{cases}$$

      The parameter α must be estimated from the histogram of $anom(x,y)$, or some other method.

– **Compute Road Score Image:**

For each possible road center position x and road width w compute the following:

$$score^2(x,w) = \beta \cdot \text{vertical-variance}(x,w) + \text{horizontal-asymmetry}(x,w)$$

$$\text{vertical-variance}(x,w) = \sum_{\frac{-w}{2} \leq i \leq \frac{w}{2}} var_y(I', x+i, N_y/2, N_y)$$

$$\text{horizontal-asymmetry}(x,w) = \frac{1}{N_{good}} \cdot \sum_{0<i\leq \frac{w}{2}} \sum_{0\leq y<N_y} (I'(x+i,y) - I'(x-i,y))^2$$

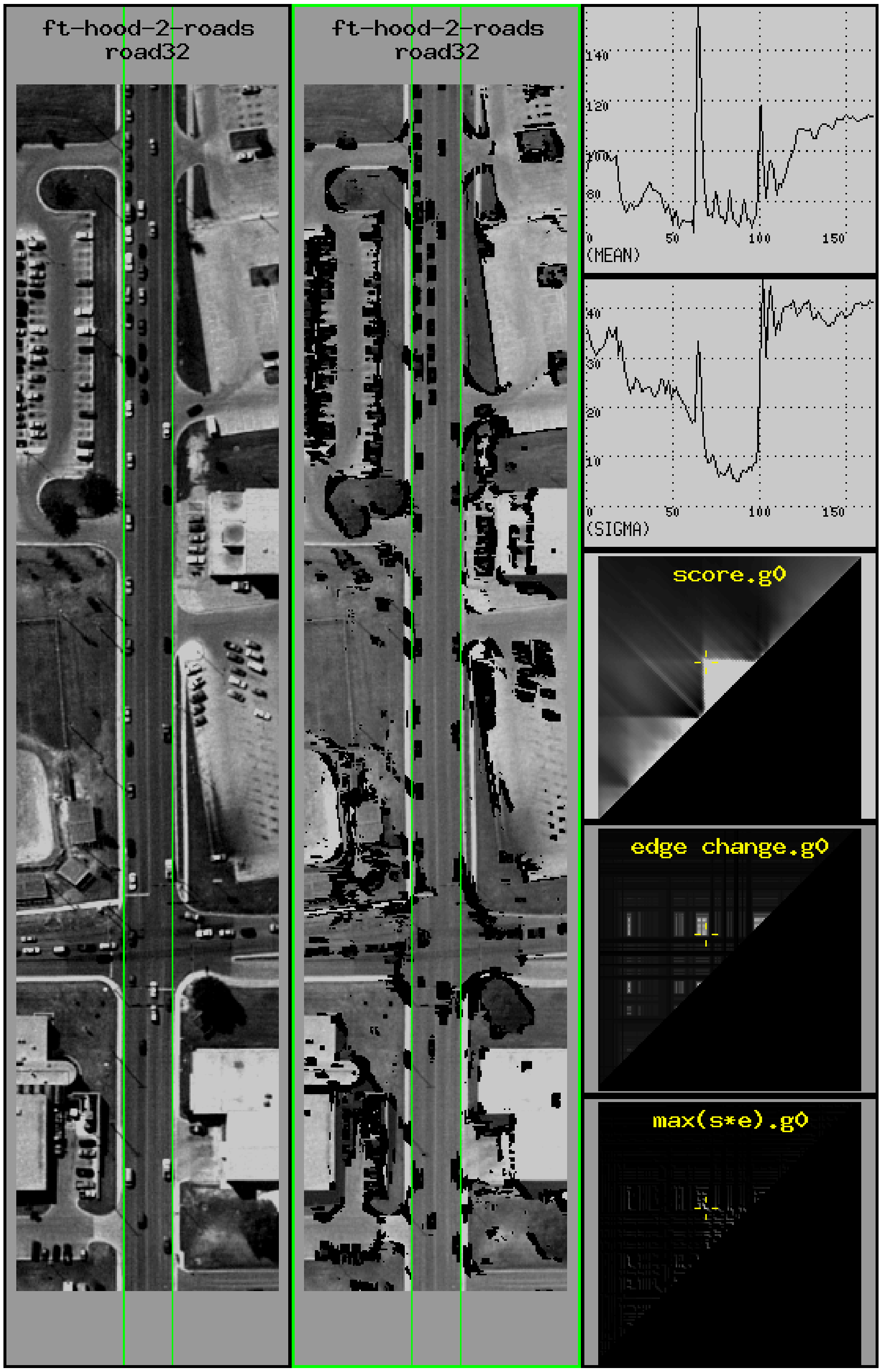
where β is a weight (usually = .5) for the vertical column variances.

In the above calculations of road score, anomalous pixels ($I'(x,y) = 0$) are excluded from the calculations. N_{good} is the number of pixel pairs where neither $I'(x+i,y)$ nor $I'(x-i,y)$ is anomalous.

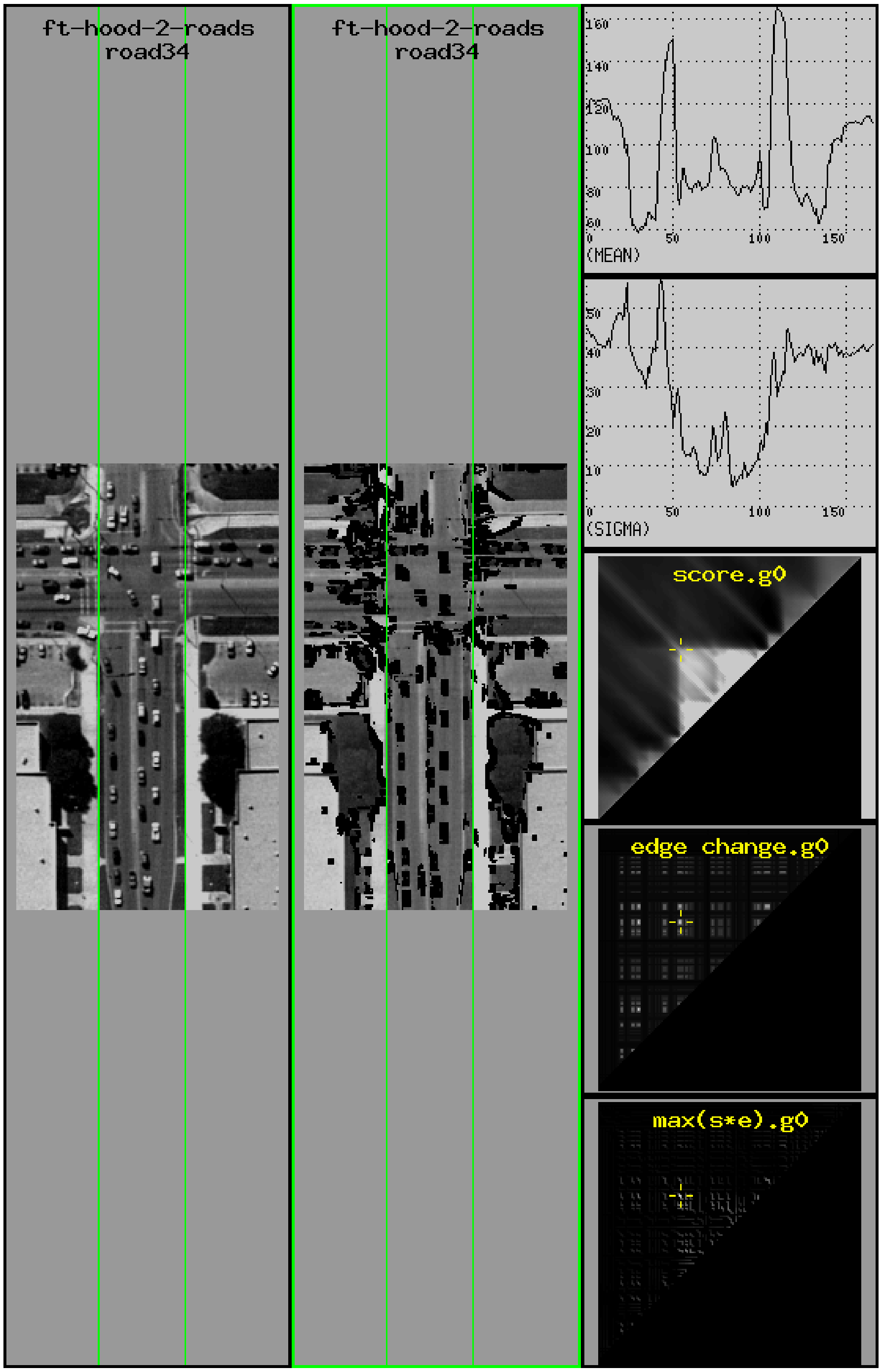
– **Compute Road Lane Structure:**

The road score image exhibits dark vertical bands corresponding to the positions of lane road center candidates. More research is needed to understand how to extract the best estimate of road width and lane structure.

- Complex Road Example



- Intersection Example



- Non-road Example