Intelligent Fusion and Analysis of AIRSAR Data for SEIDAM

A. S. (Pal) Bhogal, David G. Goodenough, Daniel Charlebois,
Hugh Barclay, Stan Matwin[1] and Olaf Niemann[2]

Pacific Forestry Centre, Victoria, BC, Canada
[1]University of Ottawa, Ottawa, Canada
[2]University of Victoria, Victoria, Canada

Abstract - **SEIDAM (System of Experts for Intelligent Data Management) intelligently fuses and analyzes remotely sensed data, such as from NASA's AIRSAR. Software agents assist the users in processing by providing the necessary information to successfully complete the sequence of tasks. These tasks include calibration, topographic corrections, and geocoding of AIRSAR data. The resulting geocoded imagery is subjected to image processing algorithms fused with GIS data in order to extract information on the biophysical parameters of forest objects. In this paper, the use of AIRSAR data for the estimation of biomass from P-band SAR for a test site on Vancouver Island is discussed, as well as the retrieving and adapting of plans for intelligently solving queries requiring radar data.**

I. INTRODUCTION

As part of NASA's Applied Information Systems Research Program, a project is being conducted to create an intelligent system, SEIDAM [1], which manages and fuses remote sensing data from aircraft and satellites with multiple geographic information systems (GIS) in order to respond to queries about forests and the environment. SEIDAM integrates several key technologies: image analysis for remote sensing data, geographical information systems (both vector and raster based), artificial intelligence (AI), modeling (growth and yield) and multi-media/visualization. User queries range from simple relational database queries to complex queries such as the update of digital forest cover GIS files. This second type of query requires SEIDAM to automatically perform image analysis tasks to extract surface features necessary to update the digital maps. One of the needed attributes is a measurement of timber volume.

Canada's most important renewable resource is the forest. Canada has 56% of the global share of newsprint exports, and 32% of the global exports of pulp. The province of British Columbia contains more than 40 % of the country's marketable timber.

The management of a vital resource such as forestry is a complex task requiring the integration of many data sets and data sources. Expert systems can be used for automating data integration, image interpretation, and determining the changes in various environmental parameters over time.

In this paper, we present some results pertaining to the computation of biomass using multi-temporal radar data acquired during the SEIDAM field programs in 1993 and 1994. We also suggest how calibrated SAR data may be fused with GIS data for use in the context of SEIDAM's expert systems for answering user queries intelligently.

A brief overview of the SEIDAM components is presented in the next section, followed by a discussion of observations made from SEIDAM AIRSAR data acquired in 1993 and 1994.

II. SEIDAM: THE SYSTEM

As figure 1 [2] shows, there are several components to SEIDAM: the main expert system, the reasoning system, the Smart Access software agents, the remote sensing software agents, the GIS software agents, the image and GIS metadata database, the image and GIS data recorded on a robotic mass data storage device, the SEIDAM knowledge base, and the reasoning system's case-base.

The SEIDAM expert system is the task master for the whole system. It has three main functions: interact with the user in order to determine the type of information the user needs (e.g. digital maps, tabular summaries, etc.), activate the Smart Access software agents in order to make all information relating to the user needs available to the reasoning system, and activate the reasoning system.

The interaction with the user is accomplished via a windows based graphical user interface (GUI). The user selects the type of products or functions that will answer his or her needs and then selects a set of 1:20000 TRIM digital maps that cover the area of interest.

SEIDAM will then activate the Smart Access [2] software agents. These agents will submit SQL queries to a relational database management system. The queries are made to extract

0-7803-3068-4/96$5.00©1996 IEEE

information from a remote sensing and GIS metadata database. This information describes ownership, source, location, distribution privileges, processing history and other ancillary information relating to the radar and GIS data available for SEIDAM. The GIS metadata database complies with the US Federal Geographic Data Committee's standard. Smart Access produces tabular reports identifying the available and necessary data that will satisfy the user's needs.

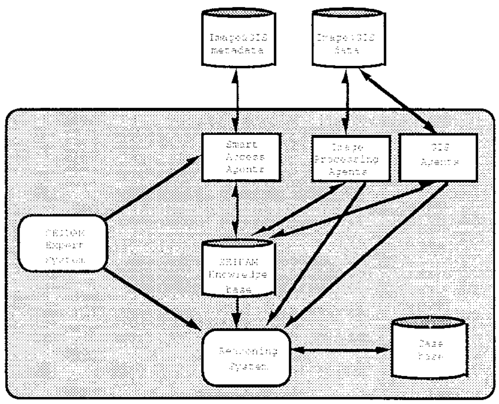

Figure 1 - SEIDAM (after [2])

Once the Smart Access software agents have completed their tasks, SEIDAM calls on the PALERMO reasoning system. PALERMO [8] is a case-based reasoning system that uses STRIPS [9] planning operators to elaborate plans. For SEIDAM, these plans correspond to the sequence of processing tasks (image analysis and GIS tasks) that must be carried out on the remote sensing and GIS data to answer user queries. Once PALERMO has formulated a plan, it will attempt to execute it by activating the image and GIS software agents.

The image analysis agents and GIS agents perform two roles: they run off the shelf software (e.g. PCI or ENVI image analysis, ESRI Arc/Ingres GIS, etc.) to perform low granularity tasks such as creating digital elevation models (DEMs); they also create STRIPS descriptions of the tasks they perform and send them to the PALERMO reasoning system, thus enabling PALERMO to create plans.

There are approximately 40 remote sensing and GIS software agents which perform such specialized tasks as: copying files, translating data between image file formats and GIS file formats, creating digital elevation models from point elevation data, moving amongst various GIS file formats; applying topographic relief correction algorithms to remote sensing imagery, computing biomass from AIRSAR measurements, etc.

III. AIRSAR DATA PREPARATION AND ANALYSIS

During the SEIDAM field programs of 1993 and 1994, NASA acquired system multi-frequency and multi-polarization AIRSAR data over the SEIDAM test sites. Data were acquired in both years over two test sites on Vancouver Island, the Greater Victoria Watershed District (GVWD) and Clayoquot Sound.

The GVWD test site is the primary SEIDAM test site. Over 90 percent of the trees found there are Douglas Fir. The average elevation of this test site is about 400 meters above sea level, with slopes as great as 22 degrees for some of the 10 plots. The younger stands are managed, but the old growth forest in this test site is largely unmanaged. The GVWD test site contains some of the oldest stands of Douglas Fir in the southern half of Vancouver Island. Studies in the GVWD test site conducted by the Canadian Forest Service have shown that trees having a diameter at breast height (dbh) of over 30 centimeters will seldom grow more than one millimeter per year in dbh [3]. Annual volume increments per hectare in Douglas Fir under the environmental conditions present at the GVWD range from 10 percent of standing volume at age 24 years, to about 5 percent by age 40, declining to near zero in older stands [3]. Based on this information, it was assumed that the change in biomass at each of the plots was negligible over the two years. Radar data were available for eight of the ten plots in the GVWD test site. The biomass values for these plots were calculated using relationships derived from several years of ongoing studies conducted by the Canadian Forest Service in the GVWD area [4].

In order to assist with the calibration of AIRSAR data, trihedral corner reflectors were deployed in the GVWD test site in both 1993 and 1994. POLCAL [5] was used to check the radiometric fidelity of the AIRSAR data. Target analysis of the corner reflector signal returns using POLCAL indicated that the AIRSAR HH/VV ratios and HH and VV phase differences were within 5 percent of expected values.

DEMs were extracted from 1:20000 scale topographic GIS data for the GVWD, (which exists as ungeneralized digital elevation points). The DEMs were registered to slant-range AIRSAR data and topographic calibration was carried out using POLCAL.

Figure 2 indicates the behavior of the normalized backscattering coefficient (σ^0) from AIRSAR data for the years 1993 and 1994, as a function of biomass for P-band. The curves agree with each other to within 3 db (worst case). We have observed similar behavior observed for σ^0_{VV} and σ^0_{HV}. In the absence of a greater number of points, it is not possible to reproduce the complex regression equations given by various sources (e.g. [6], [7]) relating biomass to the backscattering coefficients of HH, HV, their squares, and their differences. However, we were able to determine a simpler relationship between σ^0_{HH} and biomass for our data. The results were:

$\sigma^0_{HH} = 2.711 \log(B) - 13.086$ for 1993 data ($r^2 = 0.702$),
$\sigma^0_{HH} = 2.960 \log(B) - 11.892$ for 1994 data ($r^2 = 0.676$).

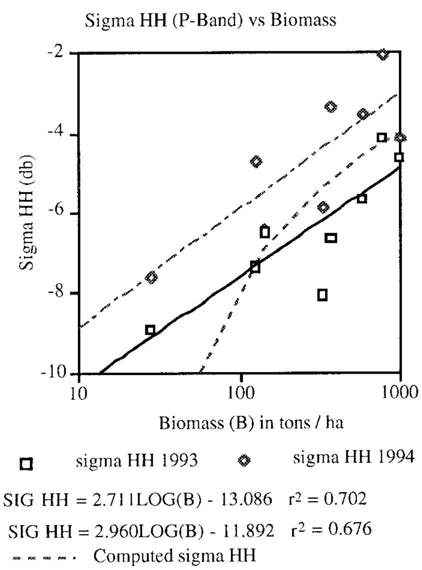

Figure 2 -Backscattering coefficient for P-band, HH polarization, as a function of biomass (B) in metric tons per hectare. The solid line show the relationship for 1993 and the dash-dot line the relationship for 1994 acquisition. The dashed curve is a relationship taken from [6].

The conditions for 1993 and 1994 differed in the amount of moisture in the ground. The earlier year was wetter than 1994. The considerable scatter in the measurements weakens the utility of AIRSAR for operational timber volume estimation at this time. In fact, when we invert these equations to predict biomass, the estimates have too much scatter. We are adding additional plots to the regression in order to elucidate other factors and to build confidence in biomass estimation from P-band SAR.

IV. AIRSAR EXPERT SYSTEMS

The process of using AIRSAR data towards the goal of determining forest biomass within SEIDAM may be conceptualized as per reference [2]. A user initiates the process of performing forest inventory determination using the SEIDAM expert system. Digital maps are selected by the user corresponding to the area of interest. Smart Access software agents are started which use the relational DBMS where the GIS and remotely sensed (AIRSAR) data reside. SQL queries are submitted which identify the appropriate GIS and AIRSAR data as well as the level to which these data have been processed. These meta data are then transferred to the knowledge base.

The SEIDAM case-based reasoning system is then activated with a goal of determining forest biomass within the selected digital maps. The STRIPS planning operator description is acquired by the reasoning system from each of the GIS and AIRSAR agents in order to determine if a similar case has been solved before. If a similar case is found, then it is modified to account for the differences between it and the current user goal. If a similar case is not found, then the reasoning system uses goal regression to determine a solution to the problem. Such a solution would consist of an ordered list of processing tasks which must be executed in the appropriate sequence to determine forest biomass, with each processing task corresponding to a single GIS or AIRSAR software agent. As each of these tasks is executed in the correct order, the contents of SEIDAM's knowledge base are modified by augmenting or deleting information. A successful execution means that the information added or deleted from the knowledge base should agree with the STRIPS planning operator provided by each software agent. This enables the reasoning system to ensure that the processing carried out by each agent is successful prior to the next agent being activated.

For the determination of the forest biomass using AIRSAR data and fusion of the same with other data sources, a solution may be formulated as follows:

- *copy_files_to_working_directory*: this agent will copy GIS and AIRSAR files from the mass storage system to a cache disk for processing.
- *trim_to_dem*: this agent would create a point elevation file readable by Arc/Info from TRIM data.
- *create_tin*: a DEM would be created by this agent from triangulated irregular network created using the point elevation file from the previous task. The output is written in a generic file format.

- *create_dem_sr*: the DEM from the previous task would be registered by the user to a slant range configuration appropriate to the NASA/JPL AIRSAR data for topographic calibration.
- *cal_AIRSAR*: calibrate AIRSAR data using corner reflector returns or homogenous targets.
- *topo_corr*: the POLCAL software package would be used to carry out the topographic correction to the AIRSAR data in the compressed Stokes Matrix format using the slant-range DEM from the previous task.
- *create_AIRSAR_image*: topographically corrected AIRSAR images would be synthesized using RSI ENVI.
- *SR_to_GR*: RSI ENVI would be used to make slant range to ground range correction of AIRSAR images.
- *relief_correction*: AIRSAR images would be corrected for relief effects using RIASSA, an in-house image analysis package.
- *set_georeference*: AIRSAR data would be georeferenced in anticipation of fusion with data from other sensors, such as TM, AVIRIS, etc.
- *calculate-biomass*: having derived the regression coefficients from previous experiments, biomass would be calculated as per the results described above. Other estimates would be generated based on other authors, such as [6], and [7].
- *update_GIS_attributes*: the attribute parameters for the forest cover GIS file would be updated to reflect the new estimate of timber volume.

V. CONCLUSIONS

We have presented observations made from AIRSAR data acquired over the SEIDAM test site of the Greater Victoria Watershed District in 1993 and 1994. A relationship has been derived for estimating biomass from P-band SAR. However, more calibration of this relationship is required. The sequence of expert systems for processing AIRSAR data has been outlined. This sequence has been partially implemented and will be completed once we are satisfied that the biomass estimation procedure is robust.

VI. ACKNOWLEDGMENTS

The authors thank Mr. Toby Krahn for assisting in the SAR analysis and Mrs. Gerry McElroy for assistance in the preparation of this manuscript.

VI. REFERENCES

[1] D.G. Goodenough, A. S. Bhogal, D. Charlebois, M. Heyd, S. Matwin and F. Portigal, "Knowledge-Based Imaging Spectrometer Analysis", presented at IEEE Pacific Rim Conference on Communications, Computers and Signal Processing, Victoria, B.C. May, 1995.

[2] D. Charlebois, D.G. Goodenough, A. S. Bhogal and S. Matwin, "Case-Based Reasoning and Software Agents for Intelligent Forest Information Management", paper to be presented at IGARSS 96', Lincoln, Nebraska in May, 1996.

[3] E. R. Gardner, "Fertilization and Thinning Effects on a Douglas Fir Ecosystem at Shawnigan Lake: 15-year Growth Response". Forestry Canada Information Report BC-X-319. 42 pages.

[4] A. K. Mitchell, H. J. Barclay, H. Brix, D. F. Pollard, R. Benton, and R. DeJong, "Biomass and Nutrient Element Dynamics in Douglas-Fir: Effects of Thinning and Nitrogen Fertilization over 18 Years", in press (Canadian Journal of Forest Research).

[5] POLCAL Users Manual. J. J. Van Zyl, C. F. Burnette, H. A. Zebker, A. Freeman, and B. Chapman. JPL D-7715 Version 4.0.

[6] E. J. Rignot, R. Zimmermann, J. J. Van Zyl, "Spaceborne Applications of P-Band Imaging Radars for Measuring Forest Biomass", IEEE Trans. Geoscience and Remote Sensing, Vol. 33, No. 5, Sept. 1995.

[7] E. S. Kasischke, N. L. Christensen Jr., and L. L. Borgeau-Chavez, "Correlating Radar Backscatter with Components of Biomass in Loblolly Pine Forests", IEEE Trans. Geoscience and Remote Sensing, Vol. 33, No. 3, May 1995.

[8] D. Charlebois, D. G. Goodenough, S. Matwin, A. S. P. Bhogal, and H. Barclay, "Planning and Learning in a Natural Resource Information System," presented at Canadian AI, Toronto ON Canada, 1996, pp. (in press).

[9] R. E. Fikes, P. E. Hart, and N. J. Nilsson, "STRIPS: A New Approach to the Application of Theorem Proving to Problem Solving," *Artificial Intelligence*, vol. 2, pp. 189-208, 1971.