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CAREER/EPSCoR: Geospatial Database-Driven Extraction of Information from Digital Aerial Imagery

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CAREER/EPSCoR: Geospatial Database-Driven Extraction of Information from Digital Aerial Imagery

Project Participants

Senior Personnel

Name: Agouris, Peggy
Worked for more than 160 Hours: Yes
Contribution to Project:

Post-doc

Graduate Student

Name: Carswell, James
Worked for more than 160 Hours: Yes
Contribution to Project:
Graduate Research Assistant, receiving monthly stipend and tuition.

Name: Gyftakis, Sotirios
Worked for more than 160 Hours: Yes
Contribution to Project:
Graduate Research Assistant, receiving monthly stipend and tuition.

Name: Partsinevelos, Panayotis
Worked for more than 160 Hours: Yes
Contribution to Project:
Mr. Partsinevelos is a PhD student and was added to this project to substitute James D. Carswell who completed his PhD studies and graduated in Spring 2000.

Name: King, Joshua
Worked for more than 160 Hours: Yes
Contribution to Project:
Graduate Research Assistant, M.S. student, receiving stipend and tuition.

Undergraduate Student

Technician, Programmer

Other Participant

Research Experience for Undergraduates

Organizational Partners

Other Collaborators or Contacts

Work performed under this award was used to leverage additional funding from industry. More specifically, we established a strong

collaboration with BAE Systems Inc. (San Diego, CA). They are a major firm in the area of geospatial information, producing software and hardware solutions for numerous government agencies and companies. We collaborated with them on technology transfer issues related to our automated change detection algorithms that we developed in this project. This led to further collaborations on additional research activities, providing additional support for student research, and added visibility to our work and products.

By its nature, this project did not include formal collaborators or contacts. Naturally, the PI has had informal interaction (e.g. working on papers, or attending meetings) with various colleagues during the duration of this project.

Activities and Findings

Research and Education Activities:

As outlined in the proposal, this project involved the following research tasks:
1 - Matching images to existing databases to detect changes in geographic objects;
2 - Extending these techniques to handle large scale variations; and
3 - Addressing relevant database/extraction accuracy issues.

Our activities in this project resulted in the development of three novel object extraction techniques.

First, we developed least-squares based matching (LSM) tools that use as input database object models, and are applied to digital imagery for object extraction and change detection. Our LSM methods are of high precision, and are very suitable for geographic objects whose outlines are of certain regularity (e.g. the linear outlines of buildings and other man-made structures). This technique was further extended to detect change in these objects automatically and update geospatial databases employing a 'differential template' application tool. The most comprehensive publications outlining our work on this topic are the publication [Agouris, Stefanidis & Carswell, 1999] in the Journal of Visual Communication and Image Representation, and the publication [Agouris, Beard, Mountrakis & Stefanidis, 2000] in the journal Photogrammetric Engineering & Remote Sensing. Please see the publications component of this report for full reference information.

In addition to this LSM-based approach we developed an approach based on an extension of the method of deformable contour models (a.k.a. snakes) to function in a differential mode. We call this new method 'differential snakes' and we use it to compare a GIS database record of an object to a new image. In our method we incorporate accuracy information on the pre-existing input version and an analysis of the accuracy potential of the new image. This allows us to automatically detect changes in our database content, and to update the database accordingly. This method complements our previously described work on LSM and enables it to handle elongated and more irregular linear elements (corresponding e.g. to long road segments or rivers). The most comprehensive publications outlining our findings in this area are the paper [Agouris, Stefanidis & Gyftakis, 2001] in the journal Photogrammetric Engineering & Remote Sensing and the publication [Agouris, Gyftakis & Stefanidis, 2001] in the IEEE International Conference on Image Processing.

Both techniques incorporate accuracy information and handle scale variatons when comparing an object's record to a newer aerial photo to detect changes in this object. They are fully automated solutions addressing the pressing issue of timely and accurate geospatial database revision. We have also investigated the applicability of the above issues to a variety of modern GIS needs, from updating and completing to querying and multitemporal analysis.

These two new approaches (differential LSM and snakes) also include an analysis of accuracy issues. We treat geospatial information as stochastic values (e.g. location and corresponding accuracy information). In contrast, typical processes consider geospatial information as deterministic (e.g. a road segment described by its coordinates only). Accordingly, our differential object extraction approaches are a step forward in solving problems associated with information overload encountered in modern geospatial information processes.

Parallel to these two approaches we also developed a neural network-inspired method to perform road extraction from multispectral imagery. We worked on the use of self-organizing maps (SOM) to integrate image classification and road extraction. This resulted in an innovative approach to fully automated object extraction, a critical problem in the fields of geospatial databases and image analysis. Furthermore, we are able to integrate object extraction and generalization by taking advantage of the generalization capabilities of SOM. This allows us to produce multiresolutional representations of a road, suitable for introduction in a GIS database. The most comprehensive publications outlining our findings in this area are the paper by [Doucette, Agouris, Stefanidis & Musavi, 2001] in the ISPRS Journal of Photogrammetry & Remote Sensing, and the paper by [Agouris, Doucette & Stefanidis, 2001] in the IEEE International Conference on Image Processing.

In addition to the above research activities the project included an
international workshop. This was a very successful event held in Portland, Maine in 1999, with 24 presentations by experts in the field. The workshop proceedings were publihed by Springer Verlag in their Lecture Notes in Computer Science series [Agouris & Stefanidis, 1999]. A

brief summary of the workshopós findings may also be found at http://www.spatial.maine.edu/~peggy/nsfWS.html.

Regarding educational activities, three undergradute/graduate courses have already been updated to incorporate project findings (in both lectures and laboratory assignments), and a new one, directly related to this project, has been already introduced to a select group of graduate students.

Findings:

We have already developed efficient algorithms and tools for all three approaches mentioned in the previous section. As previously mentioned, we have also collaborated with BAE Systems to investigate technology transfer issues, and we plan to collaborate with other interested firms to continue our relevant technology transfer activities.

In addition to funded research activities, this collaboration resulted in the donation of valuable digital image analysis software by major vendors (valued at tens of thousands of dollars). Beyond research, this software is also used in teaching relevant courses.

Training and Development:

The project supported two graduate students annually as research assistants. Over the duration of this award we had 4 students supported by it. One has graduated with a Ph.D. degree and is currently employed in an academic research center. A second student graduated with his M.S. degree and is currently employed by a research-oriented technology firm. The third student will have his dissertation defense next month, while the fourth one is expected to defend his dissertation next semester.

These students were directly involved in research training through the development and testing of novel algorithms and tools, and the preparation of refereed publications.

Furthermore, our project activities were/are presented to students at the graduate and undergraduate program of our Department through the courses offered by the PI.

Outreach Activities:

As originally planned, this project involves the following educational / outreach tasks:
1 - Development of new course;
2 - Modification of existing graduate courses;
3 - High-school outreach program updating;
4 - 3-Day workshop/experts meeting.

Regarding Task 1, we introduced a new course on the 'Integration of Digital Image Processing and Geospatial Databases', open to select graduate students.

Regarding Task 2, we incorporated findings of our work in current graduate courses. The new material is in the form of lectures and labs and presents research performed in this project. Reaction by the students has been very favorable.

Regarding Task 3, our high-school outreach program has been enriched and expanded as a result of this project by presentations given by students supported by this project. More details may be found in the 'Human Resources' section of this report.

Regarding Task 4, the planned workshop took place in Portland, ME on June 14-16, 1999. The results of this meeting include a proceedings volume published as part of the LNCS series by Springer Verlag, and an on-line summary of findings accessible through the project website.

Journal Publications

P. Agouris, A. Stefanidis & J.D. Carswell, "Sketch-Based Image Queries in Topographic Databases", Journal of Visual Communication and Image Representation (Academic Press), p. 113, vol. 10 (2), (1999). Published

P. Agouris, S. Gyftakis & A. Stefanidis, "Using a Fuzzy Supervisor for Object Extraction within an Integrated Geospatial Environment", International Archives of Photogrammetry and Remote Sensing, p. 3/1, 191, vol. XXXII, (1998). Published

P. Agouris, A. Stefanidis & J.D. Carswell, "Digital Image Retrieval Using Shape Based Queries", Spatial Data Handling, p. 613, vol. , (1998). Published

P. Agouris & A. Stefanidis, "Intelligent Image Retrieval from Large Databases using Shape and Topology", IEEE International Conference on Image Processing (ICIP), p. II-779, vol. 2, (1998). Published

P. Agouris, A. Stefanidis & J.D. Carswell, "A Feature Library Approach to On-line Image Querying and Retrieval for Topographic Applications", Vision Interface, p. 490, vol. , (1999). Published

P. Agouris, J.D. Carswell, A. Stefanidis, "An Environment for Content-Based Image Retrieval from Large Spatial Databases", ISPRS Journal of Photogrammetry and Remote Sensing (Elsevier), p. 263, vol. 54 (4), (1999). Published

G. Mountrakis, P. Agouris, A. Stefanidis, "Navigating Through Hierarchical Change Propagation in Spatiotemporal Queries", Time Workshop (IEEE Press), p. 123, vol. , (2000). Published

P. Agouris, S. Gyftakis, A. Stefanidis, "Uncertainty in Image-Based Change Detection", ACCURACY: International Symposium on Spatial Accuracy Assessment in Natural Resources and Environmental Sciences, p. 1, vol. , (2000). Published

P. Agouris, G. Mountrakis, A. Stefanidis, "Automated Spatiotemporal Change Detection in Digital Aerial Imagery", SPIE Proceedings Series: AEROSENSE - Annual International Symposium on Aerospace/Defense Sensing, Simulation, and Controls, p. 2, vol. 4054, (2000). Published

P. Agouris, M. Bertolotto, J.D. Carswell, A. Stefanidis, "A Scene Similarity Metric for Matching Configurations of Image Objects", International Archives of Photogrammetry and Remote Sensing, p. 38, vol. 33, B2, (2000). Published

P. Agouris, K. Beard, G. Mountrakis, A. Stefanidis, "Capturing and Modeling Geographic Object Change: A Spatio-Temporal Gazetteer Framework", Photogrammetric Engineering and Remote Sensing, p. 1241, vol. 66 (10), (2000). Published

P. Doucette, P. Agouris, A. Stefanidis, M. Musavi, "Self-Organized Clustering for Road Extraction in Classified Imagery", ISPRS Journal of Photogrammetry and Remote Sensing, p. 347, vol. 55(5-6), (2001). Published

P. Agouris, A. Stefanidis, S. Gyftakis, "Differential Snakes for Change Detection in Road Segments", Photogrammetric Engineering and Remote Sensing, p. 1391, vol. 67(12), (2001). Published

A. Stefanidis, P. Partsinevelos, P. Agouris, "Automated Spatiotemporal Scaling for Video Visualization", IEEE International Conference on Image Processing (ICIP), p. , vol. , (2001). Accepted

A. Stefanidis, P. Partsinevelos, P. Agouris, P. Doucette, "Summarizing Video Datasets in the Spatiotemporal Domain", Database and Expert Systems Applications (DEXA) Proceedings, p. 906, vol. , (2000). Published

P. Agouris, S. Gyftakis, A. Stefanidis, "Dynamic Node Distribution in Adaptive Snakes for Road Extraction", Vision Interface, p. 134, vol. , (2001). Published

P. Agouris, P. Doucette, A. Stefanidis, "Spatiotemporal Cluster Analysis of Elongated Regions in Aerial Imagery", IEEE International Conference on Image Processing (ICIP), p. 789, vol. 2, (2001). Published

P. Agouris, S. Gyftakis, A. Stefanidis, "Quality-Aware Deformable Models for Change Detection", IEEE International Conference on Image Processing (ICIP), p. 805, vol. 2, (2001). Published

A. Stefanidis, P. Agouris, M. Bertolotto, J. Carswell & C. Georgiadis, "Scale and Orientation-Invariant Scene Similarity Metrics for Image Queries", International Journal of Geographical Information Science, p. , vol. 16(8), (2002). Accepted

F. Fonseca, M. Egenhofer, P. Agouris & G. Camara, "Using Ontologies for Integrated Geographic Information Systems", Transactions in GIS, p. 231, vol. 6(3), (2002). Published

G. Mountrakis, P. Agouris & A. Stefanidis, "A Differential Spatiotemporal Model: Primitives and Operators", Advances in Spatial Data Handling, p. 255, vol. 10, (2002). Published

Books or Other One-time Publications

P. Agouris, A. Stefanidis (Eds.), "Integrated Spatial Databases: Digital Images and GIS", (1999). Book, Published
Editor(s): P. Agouris, A. Stefanidis (Eds.)
Collection: Integrated Spatial Databases: Digital Images and GIS
Bibliography: Lecture Notes in Computer Science, Vol. 1737, Springer Verlag

P. Doucette, P. Agouris, M. Musavi, A. Stefanidis, "Automated Extraction of Linear Features from Aerial Imagery Using Kohonen Learning and GIS Data", (1999). Book, Published
Editor(s): P. Agouris, A. Stefanidis
Collection: Integrated Spatial Databases: Digital Images and GIS
Bibliography: Lecture Notes in Computer Science, Vol. 1737, Springer Verlag

Web/Internet Site

URL(s):

http://www.spatial.maine.edu/~peggy/CAREER.html
http://www.spatial.maine.edu/~peggy/nsfWS.html

Description:

The first URL is the project page and the second is the URL of the workshop that was organized as part of this project.

Other Specific Products

Product Type: Software (or netware)

Product Description:

- Tools for image-based road extraction and change detection using differential snakes and self-organizing maps.
- A tool for building change detection using differential LSM.

Sharing Information:

These tools have been presented to NIMA personnel. NIMA is the National Imagery and Mapping Agency. Our tools have also been included in NIMA's Pathfinder program, in particular its Automatic Feature Extraction (AFE) component. We have also collaborated with BAE Systems (San Diego, CA) to exploit technology transfer opportunities. In addition, our tools have been presented to various government and defense agencies and organizations. We intend to continue working on relevant technology transfer issues beyond the duration of this project and we have already been contacted by interested parties.

Contributions

Contributions within Discipline:

This project aimed at advancing science in digital image processing andanalysis, and spatial databases. Towards this goal, we have developed new algorithms for automated object extraction and change detection. We did so by integrating these operations within a GIS environment. By embedding object extraction processes within the framework of spatial information systems, digital image processing and analysis benefited from advantages offered by the availability of spatial data from various sources and in diverse formats. At the same time, digital image analysis contributed to the improvement of the temporal and quantitative quality and completeness of geospatial databases.

Contributions to Other Disciplines:

This project was interdisciplinary by nature since it bridged GIS and digital image analysis. Furthermore, our efforts complemented and were complemented by parallel advancements in a variety of related disciplines, most notably digital libraries, spatio-temporal databases, and remote sensing.

Contributions to Human Resource Development:

As mentioned in previous sections, this project supported the graduate studies of four students. One has already graduated with his Ph.D. and is currently employed in an academic research center. A second student graduated with his M.S. degree and is currently employed by a research-oriented technology firm. The third student will hold his dissertation defense next month, while the fourth one is expected to defend his dissertation next semester. All of these students worked as Graduate Research Assistants. The research work they performed for this project was/is the core of their dissertations/theses.

Furthermore, educational developments resulting from this work affected two undergraduate/graduate and one graduate course, with an average yearly participation of approximately 15 students per class. Based on statistics over the last few years, approximately 1/4 of these students are minorities or women.

Work performed in this project has also been part of our outreach program 'Expanding your Horizons', which is directly addressing female high school students, in an effort to increase their participation in science and engineering disciplines.

Contributions to Resources for Research and Education:

This CAREER project has been important for the PI since it enabled the creation and initial support of the Digital Image Processing and Analysis Laboratory at the University of Maine. Our work in this project has been instrumental in enabling us to attract substantial funding for other complementary projects from NASA (1997), NIMA (1998, 2002), the Digital Government Program of NSF (2000), BAE Systems (2000), and the NSF ITR program (2001) that ensured the sustainability and advancement of our lab. This has strengthened our group enormously, as well as our research activities, and our potential. It should be noted that our Digital Government award and relevant partnerships resulted after initial discussions of the PI with colleagues at the 1999 IDM PI Workshop in LA, while the ITR project partnership resulted from connections established during the workshop that was part of this CAREER project.

Contributions Beyond Science and Engineering:

No such contributions were expected to be made directly through this project. However, indirectly, we expect that our work in this project will facilitate the availability of, and access to more reliable, accurate, and timely geographic information.

Categories for which nothing is reported:

Organizational Partners