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GeoModeler - using ArcEngine and Java to link a GIS front-end with a modeling back-end

FY 2005 Proposal to the NOAA HPCC Program

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Proposal Theme: Disaster Planning, Mitigation, Response and Recovery with aspects of Technologies for Collaboration, Visualization, or Analysis

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GeoModeler - using ArcEngine and Java to link a GIS front-end with a modeling back-end

Proposal for FY 2005 HPCC Funding

Prepared by: Tiffany C. Vance

Executive Summary

In responding to natural and manmade crises, researchers need to be able to rapidly gather data, define interactions, model systems and support decisions and remedies. Tools that make any of these steps faster, easier and simpler contribute to the ability to make better decisions. These tools should allow researchers to expand the types of data that can be used and integrate data from a variety of sources.

Geographic information systems (GIS) have great abilities to organize, analyze and display geospatial information. They can provide data for input to decision support technologies and crisis response systems. Models allow scientists to investigate cause and effect, test scenarios and understand patterns. Models are also able to handle time-varying and multidimensional datasets that a GIS is currently unable to process. A model can be loosely linked with a GIS.

GIS packages are starting to expose code and objects to allow closer coupling of core GIS functionality and analytical/modeling tools. With this proposal, we will investigate directly integrating GIS and modeling capabilities in support of management and decision making. Through the use of Java-based API's and connectors, GIS will be directly linked with models. Scientists and managers will be able to use a GIS-based graphical interface to display datasets, select the data to be used in a scenario, set the weights for factors in the model and run the model. The results would be returned to the GIS for display and spatial analysis.

Problem Statement

In responding to natural and manmade crises, researchers need to be able to rapidly gather data, define interactions, model systems and support decisions and remedies. Tools that make any of these steps faster, easier and simpler contribute to the ability to make better decisions. These tools should be able to expand the types of data that can be used and integrate data from a variety of sources. Two important tools are the use of decision support models and geographic information systems (GIS). Unfortunately, these two tools have not been well integrated for scientific uses.

GIS's have great abilities to organize, analyze and display geospatial information. They can provide data for input to decision support technologies and crisis response systems. Models allow scientists to investigate cause and effect, test scenarios and understand patterns. Models are also able to handle time-varying and multidimensional datasets that a GIS is currently unable to process. A model can be loosely linked with a GIS. A GIS is able to take model output - usually with considerable reformatting - and display it in a geographic context. Models are able to use spatial data as input - but GIS data often needs to be reformatted before it can be used. However, tighter integration of GIS and models has been limited. In most applications, data are created in a GIS, manually transferred to a model or decision support system and the results may or may not be returned to the GIS. This lack of true integration hinders the ability of managers and scientists to create interactive, GIS-based, models for management and research.

Two NOAA activities that have identified a need for such tools are the joint NMFS-states

Southeast Area Monitoring and Assessment Program (SEAMAP) and the NOS National Marine Sanctuaries West Coast Information Management and Delivery Program. SEAMAP is "a state/federal/university program for the collection, management and dissemination of fishery-independent data and information in the southeastern United States." The NOAA Coastal Data Development Center (NCDDC) is working to develop metadata for the SEAMAP database, and to geospatially enable raw data extracted from the SEAMAP database through an NCDDC-developed Internet gateway. They are also developing map server outlets for these data. The goal of this effort is to address the needs of fishery managers to model fishery management scenarios.

Similarly, the NCDDC has entered into an agreement with the National Marine Sanctuary Program to provide management and delivery of observational data in west coast sanctuaries, beginning with data supplied by existing and new instrument moorings operated by the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO). Modeling of NMS Monitoring Program data with the display capabilities developed through this project will enable Sanctuary scientists to integrate observed data into predictions of the affects of environmental and anthropogenic variables on marine sanctuaries. In the longer term, the potential exists to support near-real time hazard response within Sanctuaries through integration with the ongoing Sanctuaries Hazardous Incident Emergency Logistics Database System (SHIELDS), which provides Intranet-based contingency plans and response tools for NMS. Such tools are critical to safeguard the marine, historical and cultural resources protected by the NMS system. Both SEAMAP and the NMS Ecological Monitoring Program are strongly amenable to ecosystem observation modeling and derived GIS display of modeling products. GeoModeler would contribute to the HPCC goal of improving technology for access and increasing mission effectiveness by streamlining the integration of GIS data with impact models.

The proposal fits into the GIS component of "Disaster Planning, Mitigation, Response and Recovery" in that these tools can support the response of NOAA to natural and man-made disasters. Links with the Sanctuaries program will allow us to undertake research into technology that can better serve NOAA missions in this area. This project will focus on tools that expedite the transfer of spatial data to coastal professionals and emergency managers and enhance analyses used for disaster preparedness and response activities. The integration of a GIS with models will create innovative tools and user interfaces that will enhance impact modeling and decision-support activities. As the tools we develop can be deployed without a full ArcGIS license, we hope to make them widely available to better integrate field activities during disaster response.

This proposal fits with the objective of "Technologies for Collaboration, Visualization, or Analysis" in that it will provide advanced enabling technologies for analysis and applications sharing resulting in advanced analysis and visualizations. Successful deployment of these technologies will require cooperation among NMFS, OAR, NESDIS and NOS. The tools we develop will be extensible, scalable and available for easy deployment throughout NOAA. The applications will be designed using a framework approach that enables the models (Java) to be integrated with other related packages (Java3D for visualizations) and interfaced with major off-the shelf software products (ArcEngine). We plan is to develop this framework for a broad range of users.

Proposed Solution

Ideally, one would be able to link a model directly with a GIS and data could be exchanged seamlessly. A GIS front-end would allow the user to choose datasets, define model structures and select parameters for a scenario. The model itself would combine spatial analytical tools from the GIS world with scientific modeling abilities from the theoretical realm. Use of high end processors for the models would create an almost real-time interaction between the model back-end and the GIS front-end. Users would be able to describe a scenario, generate results and rerun the scenario with altered parameters in a timely and efficient manner. The results would be enhanced by the automatic generation of maps and geospatial displays.

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The project would create a framework for back-end models that would incorporate Java-based models. ArcGIS Engine and implementations of ArcObjects would be used to communicate with an ArcGIS based front end. The front end would provide both setup - allowing the use to specify the datasets to be used, the weights for elements of the model and the output desires and for display - showing the results of the model run in a map or other spatial output. With the use of the Java connector to ArcIMS, the results could also be used in an ArcIMS or other map server.

ArcEngine is an ESRI developer product for creating and deploying ArcGIS solutions. It is a simple API-neutral cross-platform development environment for ArcObjects - the C++ component technology framework used to build ArcGIS. ArcObjects are the core of the ArcGIS functionality and include tools such as overlay - union, intersect; proximity - buffer, point distance; surface analysis - aspect, hillshade, slope; and data conversion - shapefile, coverage and DEM to geodatabase. ArcEngine's object library makes full GIS functionality available though fine and coarse-grained components that can be used in Java and other environments. Using ArcEngine, one can build solutions and deploy them to users without requiring the ArcGIS Desktop applications (ArcMap, ArcCatalog) to be present on the same machine. It supports all the standard development environments, including Java, and C++, and all the major operating systems. In addition, one can embed some of the functionality available in the ArcGIS extensions. This product is a developer kit as well as deployment packages of ArcObjects technology. Using ArcEngine we will integrate GIS functionality into an application with the data being available for calculations in non-GIS components. We will also be able to make these tools available to ArcIMS sites. ArcIMS has a limited set of spatial capabilities but it is capable of interfacing with the Java API via the Java Connector. This will allow the ArcIMS community to utilize tools built with this proposal.

Major activities:

1. Work with potential customers (Sanctuaries and SEAMAP) to define scenarios to model
2. Location of static and real-time datasets for use with the models.
3. Design of GIS front-end. Creation of model framework.
4. Selection and implementation of model(s) for back-end

5. Implementation of ArcGIS Engine as connector, exploration of Java connector to ArcIMS
6. Generalization of GIS <-> model linking
7. Integration with other decision-support aids such as SHIELDS
8. Application to ArcIMS site - possibly the SIMON site.

Analysis

Extending GIS functionality beyond analysis to scientific modeling would enhance the ability of NOAA scientists to evaluate and respond to crises. In comparison with the alternative of continuing to use models that are loosely linked with a GIS an integrated system would be faster, easier and amenable to scaling up to grid compute servers. Benefits would include faster and better responses to a variety of crises. The linking of GIS and models would also provide multi-dimensional options for GIS analyses

Appropriateness

With the proposal we aim to create a linking of GIS and modeling that will be available to users in a variety of NOAA sites. The system created will be modular and reusable for future implementations. Making such a system available both to local scientists and to a wide range of scientific and general users should enhance the timeliness of the model runs and the overall usefulness of the data. Application of the links created for the first examples to other analyses should follow rapidly. Various possibilities exist for taking advantage of these analytical and descriptive tools during a crisis or natural disaster. Rapid use of a GIS model during a crisis would allow modeling of the situation, tracking of events, determination of sampling locations and development of response plans. These analyses could be created and served to various elements of NOAA and other agencies.

Technology

The project will take advantage of developments both in GIS and modeling technology. ArcEngine is the state-of-the-art for integration of GIS functionality in applications. The portability of Java and use of the NGI will allow interaction with larger datasets and may allow for distributed computation. Use of the models will enable us to make the comparison and computation techniques available within geographically distributed research groups. Using the newly available ArcEngine for access to the ArcObjects and models will enhance existing capabilities. We also hope to explore the scalability of such a system. While grid compute applications for GIS are very new (http://www.geongrid.org/), ArcGIS is enabled for grid computing and is reported to scale well in blade computing frameworks.

Scope

The mapping and analysis capabilities developed under this proposal will see extensive use by NOAA West Network members at PMEL (OAR) and AFSC (NMFS) and at NCDDC. With the distribution of the toolkit, we will make the GeoModeler capabilities available to all users of these NOAA sites, including State and other collaborators and the public. All of the applications are typical examples of NOAA data and we hope that the prototype we develop will be applicable to a number of NOAA projects. With the acceptance of ArcGIS as a defacto GIS standard, technology transfer to other GIS systems within NOAA should be fairly rapid. The tools will be able to be implemented in existing and future ArcIMS servers. The framework

should also provide an example for the NOAA Enterprise GIS efforts

Leverage
This project will leverage off of existing HPCC and ESDIM projects that have developed visualization and analysis tools. It will take advantage of techniques and algorithms developed in the JavaGIS project (FY04), the WebMapCalculator project (FY02), IMS (FY00) and 3D mapping capabilities (FY99). It will also leverage off of PMEL and AFSC's beta testing of the ArcEngine product and NCDDC's extensive experience with ArcIMS development. The melding of the newer tools with ArcGIS and ArcIMS will allow us to leverage off of the considerable data holdings and map servers that already exist. Development of GIS and Web resources have been funded by programs including ESDIM, HPCC, various States and the Coastal Ocean Program.
Cost/benefit
The benefits of this project will be enhanced by the fact that the costs of the development of the modeling and oceanographic analysis tools have already been borne by various NOAA projects. We are starting with full-fledged visualization and analysis tools that have been developed at PMEL and elsewhere. The HPCC-funded WebMap Calculator project has already explored the interaction of ArcIMS and Java/JSP. The HPCC-funded JavaGIS project has explored the use of ArcGIS Engine and we will be able to apply that experience to this project. No data location or processing should be necessary. NCDDC and AFSC will be providing matching funding for personnel and computer support equivalent to $25,000.

Performance Measures
1. Creation of an integrated GeoModeler linking GIS and modeling
2. Implementation for Sanctuaries and SEAMAP projects
3. Definition of framework for other models
4. Production of documentation

Milestones
Month 1 Work with customers (Sanctuaries and SEAMAP) to define scenarios to model
Month 2 Locate of static and real-time datasets for use with the models.
Month 3 Design of GIS front-end
Month 4 Select and implement model(s) for back-end
Month 6 Implement of ArcGIS Engine as connector, exploration of Java connector to ArcIMS
Month 8 Generale of GIS <-> model linking
Month 10 Integrate with other toolsets such as SHIELDS
Month 11 Apply to an ArcIMS site - possibly the SIMoN site for the Monterey Bay Sanctuary.
Month 12 Documentation written

Deliverables
- framework for integrating models
- GIS based front end for model setup
- Java ArcEngine based connector
- full model system for one or two example applications
- documentation and distributable version of all code