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JavaGIS - integration of ArcObjects, Java and Java3D components for a scientific GIS

FY 2004 Proposal to the NOAA HPCC Program

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

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JavaGIS - integration of ArcObjects, Java and Java3D components for a scientific GIS

Proposal for FY 2004 HPCC Funding

Prepared by: Tiffany C. Vance

Executive Summary:

Ideally, scientists should be able to format, explore, analyze and visualize data in a simple, powerful and fast application that would seamlessly integrate georeferenced data from a variety of data sources into a powerful intuitive visualization. Geographic information systems (GIS) provide a high level of functionality for spatial analyses but are not yet able to provide the extended functionality needed to create a truly "scientific GIS". Java can be used to program scientific calculations and analyses but it isn't inherently spatial. VRML provides the ability to visualize scientific data and to allow the user to interact with the data by rotating, zooming and panning but you cannot easily query VRML objects. Recent developments in GIS and in Java could be exploited to produce a prototype of this kind of integrated scientific system.

In this project we propose to use a combination of Java/Java3D and the recently introduced ArcEngine product to create a prototype for a scientific GIS. We will combine the spatial tools exposed through the ArcEngine with the analytical capabilities of algorithms written in Java with the complex visualization capabilities of Java3D. Modules from each of these technologies will be combined to create innovative tools to allow users to import data, perform spatial and scientific analyses and output the results as visualizations for further examination.

Problem Statement:

Ideally, scientists should be able to format, explore, analyze and visualize data in a simple, powerful and fast application that would seamlessly integrate georeferenced data from a variety of data sources into a powerful intuitive visualization. Unfortunately, while various technologies provide pieces of the needed functionality, it has been hard to draw them together. However, recent developments in GIS and in Java could be exploited to produce a prototype for this kind of integrated scientific system.

Geographic information systems (GIS) provide a high level of functionality for spatial analyses but are not yet able to provide the extended functionality needed to create a truly "scientific GIS". Examples of the functionality that is lacking include time series analyses, calculation of the volume of the overlap between volumes - for example between a school of fish and a prey field, or calculation of the intersection of a vector path with a volume - for example the route of a marine mammal through a pool of cold water. Other functions might include the ability to specify a slice through a three-dimensional lattice of model output data and to make various analyses along that slice.

Java can be used to program scientific calculations and analyses but it isn't inherently spatial. Datasets can have a spatial component, but Java treats this as it would any type of coordinate system. Topology, or the spatial relationship between objects, is not stored with data. Functions such as map projections, slope calculations and spatial intersections are not native to the language. However, Java is easily extensible and functions written in other languages can be integrated.

VRML provides the ability to visualize scientific data and to allow the user to interact with the data by rotating, zooming and panning but you cannot easily query VRML objects. Ideally one would be able to point at a three-dimensional location in a VRML view and easily return the values of the variable and associated information for that location. VRML scene navigation generally requires that a separate VRML plug-in application be installed on the client system. From the user's perspective, plug-ins are poorly integrated into the browser environment since they are a separate application and often operate in a separate window from the browser. Additionally, useful plug-ins may only be available for the more popular client platforms. Recent developments in Java3D extend the functionality of VRML and answer a number of the limitations mentioned.

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 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 software (Java) to be integrated with other related packages (Java3D) and interfaced with major off-the shelf software products (ArcEngine). We aim to develop these tools for a broad range of potential users.

The proposal also fits into the GIS component of "Disaster Planning, Mitigation, Response and Recovery" in that these tools could support the response of NOAA to natural and man-made disasters. Links with the Hazmat program will allow us to undertake research into technologies that can better serve NOAA missions in this area. This project will focus on tools that convert non-spatial data to GIS compatible data, expedite the transfer of spatial data to coastal professionals and emergency managers and enhance analyses used for disaster preparedness and response 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.

Proposed Solution:

In this project, we will use the flexibility of Java to integrate GIS functionality with Java3D based visualization. Specifically we propose to use a combination of Java/Java3D and the recently introduced ArcEngine product from ESRI to create a prototype of a scientific GIS. We will combine the spatial tools exposed through the ArcEngine Java API with the analytical capabilities of algorithms written in Java with the complex visualization capabilities of Java3D. Modules from each of these technologies will be combined to create innovative tools to allow users to import georeferenced data, make spatial selections, perform spatial and scientific analyses and output the results as visualizations for further examination. Use of the ArcIMS Java Connector will allow these modules to be implemented in ArcIMS sites for web-based analysis.

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 3D API via the Java Connector. This will allow the ArcIMS community to utilize tools built with this proposal.

Java will allow us to make a variety of scientific calculations on the data and to provide the results back both to the GIS component and to a Java3D based visualization component. We will be able to take advantage of a number of Java utilities such as UNIDATA Java tools including IDV, OceanShare, ncBrowse, SGT toolkit and TimeSeries applet. The ArcIMS Java Connector could be used to produce map coordinates based that would allow data retrieval from a DODS server, and subsequent plotting with tools designed for interaction with gridded fields.

The Java 3D API is an application programming interface used for writing stand-alone three-dimensional graphics applications or Web-based 3D applets. It gives developers high level constructs for creating and manipulating 3D geometry and tools for constructing the structures used in rendering that geometry. With Java 3D API constructs, application developers can describe very large virtual worlds, which, in turn, are efficiently rendered by the Java 3D API. The Java 3D API extension is designed as a high-level platform-independent 3D graphics programming API and is amenable to very high performance implementations across a range of platforms. To optimize rendering, Java 3D API implementations are layered to take advantage of the native, low-level API that is available on a given system. In particular, Java 3D API implementations that utilize OpenGL, Direct3D API, and QuickDraw3D are available. This means that Java 3D API rendering will be accelerated across the same wide range of systems that are supported by these lower-level APIs. The Java 3D API is aimed at a wide range of 3D-capable hardware and software platforms, from low cost PC game cards and software renderers, through mid-range workstations, all the way up to very high-performance, specialized, 3D image generators. Support for run-time loaders was included to allow Java 3D API to handle a wide variety of file formats such as interchange formats, VRML 1.0, and VRML 2.0.

Combining these three technologies, we will create an application for the nowCoast project. The nowCoast project is an Office of Coast Survey effort to provide forecast model developers and the coastal community with centralized access to real-time physical, meteorological, oceanographic, river, and air/water quality information. The portal is used by NOS modelers and Hazmat users for disaster planning and response. The Web portal also provides NOAA forecasts for major estuaries, seaports, and adjacent coastal regions as well as the Great Lakes. The application this project develops will use ArcEngine and Java3D to create a GIS tool to serve 3D rendered objects of model data. It will enhance nowCoast by the addition of a number of 3D visualization and spatial analysis tools. These will include creating 2D and 3D plots from a polyline, creating 2D velocity plots from point input (columnar plot) and a capability for viewing model data in 3D using Java3D.

A second application for, the NMFS/Alaska Fisheries Science Center, will allow scientists to calculate a variety of statistics and measures about the intersection of vector and volumetric objects with volumes in 3D. The objects could include marine mammal tracklines and schools of fish and the 3D volumes might include schools of prey and water masses such as cold pools. These types of volume on volume intersections could be generalized to a number of coastal and offshore applications. They will also serve as templates for many other tasks.

Activities in this project include:
installing and testing Java3D and ArcEngine
integrating ArcObjects/ArcEngine with analysis tools in Java with visualizations in Java3D
creating the nowCoast application and creating the fisheries-oceanography application
documenting the techniques and tools we create

Analysis:

Visualizations have already proven themselves as collaborative tools. The development of geospatial analytical tools will expand their usefulness for a variety of analyses. The integration of three existing technologies will allow unique and powerful tools to be developed. The project can leverage off of existing HPCC/ESDIM funded projects for visualization, GIS technology and map servers, and NGI access. The use of Java and Java3D will make the results available as platform-independent web tools. While a desktop GIS provides these types of computations there is no equivalent functionality available via the Web for GIS datasets. Deployment of ArcEngine-based applications will allow users who do not have full-blown ArcGIS installations to take advantage of these tools.

Appropriateness

With the proposal we aim to create a suite of tools that will be available to users in a variety of NOAA sites. The tools will be modular and reusable for future implementations. Making a suite of JavaGIS analysis tools available both to local scientists and to a wide range of scientific and general users should enhance the timeliness of the data dissemination and the overall usefulness of the data. Application of the modules 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 analysis of data 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 visualization technology. Java3D is seen as a state-of-the-art technology for visualization. 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 tools 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 Java3D for advanced visualizations will enhance existing capabilities.

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 also at OCS and Hazmat (NOS), along with academic colleagues at various universities. With the distribution of the toolkit, we will make the JavaGIS capabilities available to all users of these NOAA sites, including university 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.

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 WebMap Calculator 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. 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, NSF, FEMA 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 Java-based 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 and we will be able to apply that project to this project. No data location or processing should be necessary. PMEL and AFSC will be providing matching funding for personnel and computer support.

Performance Measures:

1. Usability of the tools developed
2. Applicability of the tools and reusability of the tool modules
3. Speed of application to another project
4. Quality of the documentation

Milestones

Month 1 - Contracts issued
Month 1 - ArcEngine installation
Month 2 - Java oceanographic tools installed and tested
Month 3 - Java3D installed and tested
Month 5 - Interaction and integration of the three tools tested
Month 8 - Application to slice through model data and generate displays complete
Month 10 - Application to analyze fisheries data complete
Month 12 - Documentation complete

Deliverables

- Analysis modules in Java and Java3D implementing ArcObjects
- Application to slice and visualize 3D model data
- Fisheries oceanographic analysis and visualizations application
- Enhanced nowCoast and AFSC/PMEL map servers using the Java connector
- Documentation on implementation and integration