WEBSERVICE INTEROPERABILITY FOR EMERGENCY MANAGEMENT DECISION SUPPORT

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Abstract

The Distributed Spatiotemporal Interoperability (DALI) approach addresses the issue of Interoperability between the separate domains of geoinformation (GI) and modeling & simulation (M&S) technology. While interoperability is often limited to a specific domain, DALI tries to exploit the synergies of coupling OGC-compliant services and HLA-based simulations in a standardized manner. The paper describes the status of the evolving DALI concept in its current third development stage and takes a closer look at the latest advances in addressing open questions of cross-domain interoperability based on the OGC and HLA specifications.

Introduction

While the geographic information (GI) and the modeling and simulation (M&S) domain both offer a wealth of systems, services and concepts or architectures for interoperability, the access to services outside the "own domain" still results in proprietary solutions, leaving the need for cross-domain interoperability unaddressed.

But often processes in both the spatial and temporal dimensions need to be modeled, forecasted, analyzed for decision support and other tasks; Environmental and Emergency Management (EM) are just two example application areas [Raa+05]. The Spatiotemporal Interoperability approach (DALI) uses the Open Geospatial Consortium (OGC) specifications and the High Level Architecture for Modeling and Simulation (HLA) as domain-specific state-of-the-art interoperability technologies and strives to make the synergies of coupling OGC-compliant services and HLA-based simulations usable in a standardized manner. This paper describes the third implementation stage of DALI and some of the advances that have been made in areas that previous stages left unaddressed.

The remainder of this paper is structured as follows: Section 2 points out different forms of interoperability in the Gesospatial and M&S domain. Next, the DALI-Architecture as an approach for spatiotemporal interoperability is discussed. The different stages in the DALI development process are described in this section. Sections 4 and 5 focus on the advances of spatiotemporal interoperability in the current third development stage. The Web-Service oriented structure of the new architecture and topics like Web-based HLA-Access, using geography markup language (GML) data as federate input and the visualization of simulation

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results based on styled layer descriptions (SLD) are presented in theses sections. Lastly, an outlook concludes the paper.

Interoperability

In general, Interoperability is defined as "the ability of two or more systems or components to exchange information and to use the information that has been exchanged" [IEEE90]. In the M&S domain it is defined as "the ability of a […] simulation to provide services to, and accept services from, other […] simulations, and to use the services so exchanged to enable them to operate effectively together" [Dep. Of Defence 1994].

The complex topic of Interoperability needs to be structured in more detail and is subject to current research and development.

General Interoperability Architectures

Service Oriented Architectures (SOA) are an example of general (non domain specific) interoperability approaches and can be described as collection of services providing an ability, for example, to exchange information [Barry 2005]. Some of the first service oriented architectures were based on CORBA or DCOM technologies. Today SOA based on Webservice and XML/SOAP technology is in focus for civilian enterprise integration. Services are defined using a Webservice Definition Language (WSDL) and published in directories based on the Universal Description, Discovery and Integration (UDDI) meta-service. One of the main advantages is that Webservices are supported by a wide range of operating systems and development/deployment environments. Elements and standards used by SOAs are also commonly used by domain specific architectures and approaches, such as the Extensible Modeling and Simulation Framework XMSF, GI Services and HLA Evolved [Raape et.al. 2005].

Interoperability in the Geospatial Domain

Interoperability of the geospatial domain is currently mainly provided through the standardization bodies ISO and OGC. ISO specification series 191xx provides a rather high level view on geospatial data and processes, while OGC specifications address both the abstract as well as the implementation level. One of the most promising approaches to foster interoperability within the geospatial community is provided by the OGC, an international non-profit industry consortium.

The standardization work of the OGC is currently state of the art within the geospatial domain. Based on the ISO/IEC Reference Model for Open Distributed Processing (RM-ODP), it has produced mature specifications that provide a high level of interoperability. The OGC Webservices Framework provides a common set of interfaces and encodings that span the functional parts of the enterprise.

While all current implementation specifications provided by OGC focus on static, non temporal dynamic geospatial data, it is up to the Sensor Web Enablement (SWE) initiative to address the integration of live sensors and simulation models [Simonis et.al. 2003]. Simulation model integration can be interpreted as a special way of sensor device integration: Models predict, estimate, or simulate features by analogy with Web Feature Services (WFS) that produce features from conventional data stores. Features produced by models are commonly observations which reflect the complexity of the acquisition process and provide information about how the data was collected, where, with what kind of a sensor, when and so on. The Observation and Measurement (O&M) specification provides general models and XML encodings for observations and measurements made using sensors and became mostly part of the Geographic Markup Language (GML) [Cox et.al. 2004]. The GML observation model understands an observation as the process of observing some phenomenon. It is not a simple object with a value, time stamp and location identifier, but a complete model that gives additional information about what and how the process was performed. The Sensor Model Language (SensorML) provides models and XML Schema for describing sensor systems and observation process models [Botts 2004]. To access the spatiotemporal data, a highly specific subtype of a WFS, the Sensor Observation Service (SOS) was developed. Although a lot of integration and harmonization work with other standardization communities will have to be performed, OGC SWE is currently the most promising approach to handle dynamic geospatial information in a standardized way.

Interoperability in the Modeling & Simulation Domain

In the past decades simulations often have been specialized, monolithic applications not prepared to communicate or interoperate with other systems. It was in the military domain where the standards Aggregate Level Simulation Protocol (ALSP) and Distributed Interactive Simulation (DIS) have been developed and deployed widely to standardize synchronization among similar simulations. Based on the ALSP / DIS experiences and the requirements derived from the need to build interoperable, modular, cost-effective and flexible simulations focus shifted to Interoperability and Reusability. As a result, the US Department of Defense (DoD) triggered the development of the High Level Architecture for Modeling and Simulation (HLA) currently being the state-of-the-art architecture for distributed simulation systems.

The HLA is a software architecture and infrastructure technology for distributed simulation systems (called *Federations*) consisting of heterogeneous, distributed and dislocated subsystems (called *Federates*). HLA offers flexible communication and synchronization services to allow federates and federations to operate under a wide range of different time regimes, which also led to the participation ("HLA-enabling") of non-simulation systems like databases, sensors, etc. HLA is the prescribed DoD and NATO standard for military simulation interoperability and was adopted as open international standard IEEE 1516.

The HLA consists of three major building blocks: the *HLA Rules*, the *HLA Object Model Template (OMT)* and the *HLA Interface Specification (IfSpec)*. The Rules, OMT and IfSpec define how federations and federates shall behave, communicate and how their object models have to be described. The HLA rules describe the basic behavior of federations (rules 1-5) and federates (rules 6-10). The Object Model Template (OMT) provides a common framework for the communication between HLA simulations and consists of the Federation Object Model (FOM) which describes the shared objects, attributes and interactions for the whole federation and the Simulation Object Model (SOM) which describes the shared object, attributes and interactions used for a single federate. The Interface Specification is object oriented (with some exceptions) and divided into six service groups. The Time Management services allow the transparent management of federates under different time regimes (e.g. real time, time stepped, event driven, continuous) which is a major breakthrough compared to previous technologies. A so-called Runtime Infrastructure (RTI) is provided which offers the necessary services needed to implement the HLA.

DALI Spatiotemporal Interoperability Architecture

Often applications in Environmental and Emergency Management require dynamic information, delivered by sensor networks, simulations or archives. Sometimes different scenarios must be analysed and compared. E.g. in an emergency response application, a decision maker needs not only to have actual (if not realtime) information; in addition, to be able to forecast the spatio-temporal consequences of decision alternatives would be very helpful. On the other hand simulations often require spatial information, e.g. road networks, terrain information, infrastructures etc.

The interoperability architectures described in the previous section are limited to their respective domain. The handling of dynamic information in OGC environments is only beginning to be addressed, and the management of geospatial information in HLA environments is nearly undefined.

This section describes the DALI approach which tries to achieve interoperability also between OGC and HLA "services".

Approach

The OGC Specifications and the HLA provide a solid foundation for an spatiotemporal interoperability architecture; the key feature comparison shown in table 1 shows that in terms of the capability to model and support spatiotemporal processes in a modular and standardized way both technologies are complementary.

Criteria	HLA	OpenGIS
Domain	Time	Space
Applications	Simulation	GIS
Approach	Distributed Heterogeneous Simulation-based Systems	Interoperable Geo-enabled Web-Services
Standardization	DoD, NATO, IEEE	OGC
Temporal Awareness	Yes	No
Time Management	Yes	No
Spatial Awareness	No	Yes
Availability of Services	During Federation Runtime	Permanent
Web-based Services	No	Yes
Communication Style	Stateful	Stateless

Table 1: HLA/OpenGIS Key Feature Comparison

An integration of both standardization approaches would offer features and services accessible to both basic architectures. Table 1 also indicates what bridges need to be built between both technologies. In general, the DALI approach can be structured as follows:

- making OGC services available to HLA federates,
- making federations available to OGC services.

As a minimum, the following points have to be addressed:

- Federations must be permanently available as OGC webservice (by creating appropriate wrapper interfaces / services);
- Provisions must be made to create, start, control and terminate Federation Executions remotely (e.g. using suitable management services);
- Geographic objects must be made interchangeable. This results in a GI Reference FOM on the HLA side which has to follow the OGC Open Geodata Model as closely as possible. Achievement of semantic interoperability on the HLA side is an open research issue very important to the DALI approach.
- Specialized federates have to be created that façade selected OGC services to ensure HLA compliancy. Using HLA declaration and object management services, they will listen to GI requests within federations and will transparently collect responses from appropriate OGC services.

DALI Architecture

The DALI approach cannot cover every potential application scenario equally, and for some specific cases other (proprietary?) protocols or architectures will be a better choice. However, typical scenarios have to be defined before going into implementation details. Typical scenarios with different interactivity and synchronization requirements are [Raape 2005]:

- „Just the Results“: The system or service requesting simulation services is only interested in the results of the simulation.
- “Keep me informed”: The simulation service requester wants to be informed about the progress of the simulation run and/or about certain events (triggered by update frequencies or conditions previously defined). The communication requirements will range from the “Just the Results” level up to a level where the application of specific protocols or architectures starts to be indicated.
- “Online Visualization”: The requester wants to “see” what happens on the simulation side. Depending on the visualization requirements, this scenario might range from a static picture being refreshed every n seconds up to smooth (but non-interactive) animations.
- “Interactive online Animation”: interactive visualization requires the visualization client to be in the causality loop of distributed time management. This scenario requires the visualization and animation to be a HLA-federate participating in the federation to be monitored.

The development of specialized GI/OGC federates that mirror OGC service functionality transparently into HLA federations and the development of OGC SensorWeb services that transparently map HLA-based simulation services as “virtual sensors”, are not described in detail here. Different approaches have been evaluated to achieve permanent availability and remote control of federations.

Using the DALI architecture, much flexibility can be gained when an application can be orchestrated with specific modules / services and simulations dynamically be initialized at runtime (shift from pre-configured, sometimes hardwired initialization to on-the-fly initialization). A further DALI design principle uses the black-box feature where a simulation federate or service hides the implementation details; thus, using the same interface, the same object model can be served by a database, simulation or sensor network federate. These DALI concepts can be used to create (decision support) systems that are able to be applied in different usage scenarios ranging from analysis and planning, training and real-time decision support [Klein / Wytzisk 2001].

<u>DALI Development Process</u>

The DALI approach is being developed iteratively: at each stage of development, a set of open issues are addressed conceptually and prototypically as well as current developments in neighboring technology and standard areas are evaluated. Depending on the results of previous stages and current status of the projects where DALI work is embedded in, the next stage is planned. This section describes stages 1 and 2 of the DALI approach shortly before a closer look at the advancements of stage 3 is taken.
Stage 1: First implementation of DALI

A first Emergency Management prototype based on the DALI concept has been developed and implemented during a German R&D project and presented in [Schulze et.al. 2002] and [Wytzisk 2003]. The chosen scenario was to monitor and forecast spatially distributed runoff in a given area of Germany using a complex distributed hydrological simulation system. In addition to a set of static spatial input data provided by OGC Webservices, the simulation is parameterized by extremely up-to-date rainfall data, provided by on-line measuring points which are integrated by appropriate Geofederates. Current runoff measurements are incorporated to continuously calibrate the model during runtime integrating water level measurement points. Interoperable sub-models can be integrated to forecast high water hazards and flood damage to supply suitable information for operative emergency management. The first prototype was developed to demonstrate the basic concepts described above and to serve as the platform for additional federates and spatiotemporal services. A case study region in Germany has been chosen that allows access to a (nearly) real-time sensor network in reservoirs and rain gauges.

Stage 2: the European MEDSI Prototype

A second and updated prototype of the DALI approach has been implemented as part of the European R&D project "Management Decision Support for Critical Infrastructures (MEDSI)". The objective of MEDSI project has been to develop a web-based integrated set of software services as a tool to enhance the capabilities of crisis planners and crisis managers in both private and governmental organizations. MEDSI enables them to utilize various information sources for better monitoring and reduction of potential and actual risks and for more effective response in case of threats imposed especially to the subjects of the critical infrastructure [MEDSI 2005].
One of the MEDSI test scenarios deals with a flooding situation in the city of Magdeburg. As part of the Magdeburg prototype implementation, a generic evacuation simulation has been developed which operates in a lightweight prototype version of the DALI architecture. The application scenario describes the evacuation of 20.-30.000 people from risk-prone areas into evacuation areas and is based on the historic flood situation in the city of Magdeburg in 2002. The scenario includes a decision support system prototype to support the crisis management group of the region of Magdeburg. Modules provide the necessary geographical and non-geographical base data, and the generic evacuation simulation model was used to forecast and evaluate different evacuation scenarios under varying conditions as well as to identify potential bottlenecks during the evacuation process and the identification of critical success factors [Raape/Petjoch 2004]. According to the individual scenarios the system has already run or is currently running, an online or post-mortem visualization is possible using OGC webservices or animation software (see figure 1).

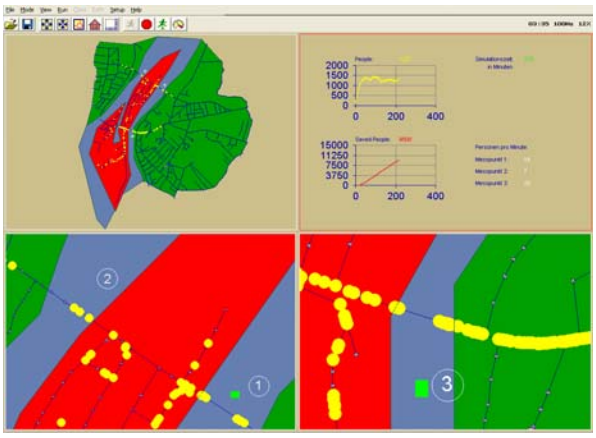

Figure 1: Animation of a single evacuation scenario

At runtime, the street network is requested from an OGC service and is made available to the HLA-based generic evacuation model. This results in ad-hoc configuration and initialization capability needed in the EM domain.

The rest of the paper describes the current stage 3 of the DALI implementation sequence, the progress made and the next steps to be taken on the way to OGC/HLA based cross-domain interoperability.

Current Stage: Web-based implementation of DALI

Overview and Prototype Architecture

Based on the experiences made, the third implementation phase described in the following uses the webservice approach to implement new capabilities and address certain shortcomings of previous stages. In order to allow the user to send a DALI parameter set (which defines the spatial or simulation services involved as well as their initial configurations and the definition of the output parameters) and receive the (simulation) results according to the request-response-pattern, a type of service chain was to be implemented.

Figure 2 shows the components of the architecture. The client (top left) communicates with a webservice façade of the GeoSim-Management-Webservice which itself provides permanent access to the HLA-based simulation functionality (one of the major requirements stated above). This central webservice is able to activate the required federates for a specific simulation as requested by the client. In order to start the required federates and get them joined into a common federation execution, the GeoSim-Management-Webservice issues requests to the webservice interfaces of the federates. Every federate therefore needs to have a webservice wrapper which provices permanent accessibility.

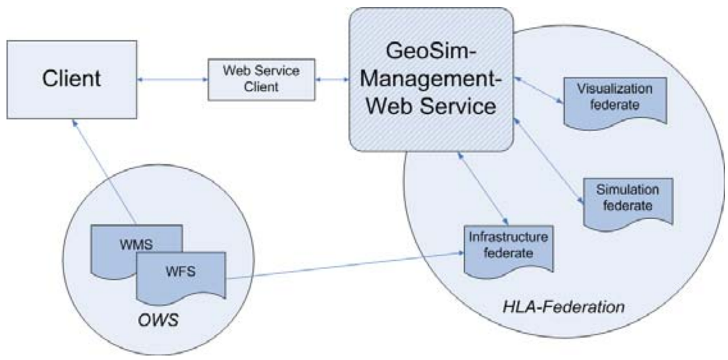

Figure 2: Structure of the architecture

The GeoSim-Management-Federate is responsible for the startup, control and shutdown of the federation and the required federates. OGC Web Map and Web Feature services (bottom left) provide the basic spatial data (in our case information about the traffic network, see below). The spatial data within the user specified rectangle (bounding box) is processed and fed into the HLA federation execution by the geofederate which is implemented as infrastructure federate in our specific prototype scenario. During the federation execution the visualization federate collects the required data to generate the results after the run.

Further details of the stage 3 concept and prototype and an additional sequence diagram can be found below. At this stage OGC SWE services have been evaluated but not been used due to the lack of available SWE implementations. In addition, the prototype uses a proprietary object model; the challenging area of generic OGC/HLA object model mapping (GML/O&M/SensorML vs. OMT, GI reference FOM) will be considered in the next development stages.

The prototype implementation uses a traffic scenario: different types of vehicles, optionally following different traffic patterns (e.g. rush-hour / transit / event-induced or evacuation traffic), are modelled by one or more traffic simulations (federates). The road network is provided by an infrastructure federate which uses OGC services to access the spatial data of the network. Additional simulations can join to model dynamic processes which may interact with the traffic and/or the infrastructure, such as weather (online weather data or weather simulations describing fog, toxic clouds, etc.) and flooding simulations which may result in impassable roads.

Depending on the usage scenario (see section 3.2), the results are published by the visualization federate during simulation runtime or after simulation completion in the user defined manner. The whole simulation process is managed by the GeoSim management webservice. It is the sole interface between simulation and client.

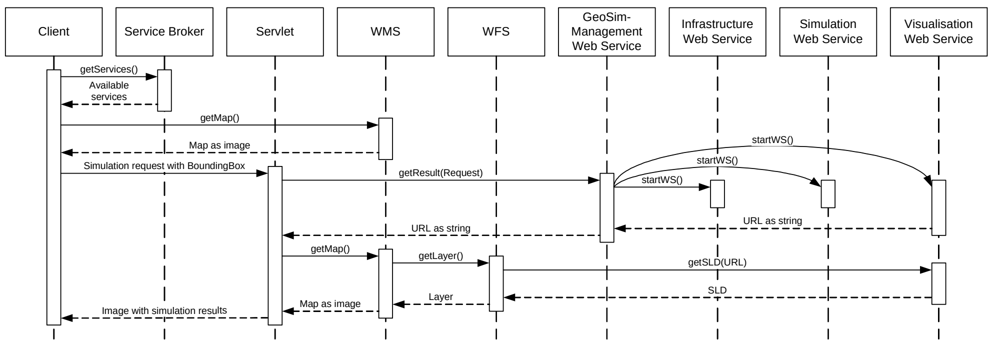

Figure 3: Sequence Diagram

Figure 3 contains an functional overview of the complete web-based implementation of stage 3 of DALI. At first the user requests a list of available WMS, WFS and GeoSim-Management-webservices. Out of this list the sources for the geodata are chosen, and the user can specify the geographic area which should be used for the simulation and other simulation parameters. Then the simulation is started by the user, and the client sends a request to the selected GeoSim-Management webservice that contains all the parameters. The GeoSim-Management webservice creates a new federation and starts the GeoSim Management federate. After the federate joined the federation successfully the GeoSim management webservice starts the other federates by sending requests to their webservic façades which in turn get their federates started and joined. When all federates joined the federation, the simulation begins and runs until the abort criterion is reached or the simulation ends. Now the visualization webservice processes the simulation results, generates a SLD file and sends back its URL. At the end a new getMap-request is send and the generated SLD affects the map so the results can be portrayed by the WMS.

Wherever possible open source software has been used. For several reasons the DMSO RTI 1.3NG software has been used which is not available for free anymore. Future work will focus on the forthcoming HLA specification (IEEE1516-2006, also known as “HLA Evolved”).

Summary and Outlook

The Distributed Spatiotemporal Interoperability Architecture (DALI) presented in this paper describes an approach to exploit the synergies of coupling OGC-compliant services and HLA-based simulations in a standardized manner. In its current third development stage, central issues like remote control of HLA components and OGC compliant visualization of results are addressed using a generic webservice based approach and by rethinking methods developed in previous development stages. The DALI architecture is under ongoing development, and still lots of issues and open questions need to be solved and answered. However, recent developments and standardization initiatives in related areas (e.g. HLA Evolved [Möller 2005], OGC OWS-3 Testbed [OGC 2005]) are encouraging if not utilizable for the overall aim of spatiotemporal interoperability.

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