

Intelligent GIS for Monitoring Systems Development

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1 INTRODUCTION

Currently GISs are being more widely used to solve problems concerning simulation of processes and situations in monitoring systems designed for different purposes. Meanwhile, as some sources note, application of universal GIS in monitoring systems is associated with a number of problems having different nature.

Development of mathematic, statistical and simulation models, data and knowledge bases, processing methods and then their integration with universal GIS results in the situation when cost of this work becomes equal and even exceeds the development cost of GIS itself. At the same time, development of a proper GIS accounting for all advantages, such as a complete source code and documentation set, do not always minimize the expenses while localizing the developed software even with one major customer.

Thereby an idea appeared to formulate several essential requirements to be met by the developed software for multi-purpose monitoring systems. Features of the development process are generally outlined by but not limited to the following requirements:

- easy and clear data and information access;
- smart and fast modification of the system's obsolete applications;
- quick integration of new applications into the work system;
- data standards and formats, and information support;
- reuse of software code and other resources;
- dynamic reconfiguration of the systems without new development and/or recompilation of the project on the whole;
- possibility of the IGIS operation on a separate PC, LAN and global networks.

These requirements result in considering GIS as a certain intelligent application with new properties, which satisfy the above requirements. From technological point of view, in order to develop similar GISs it is suggested to apply SOA concept, i.e. system decomposition into several services that enables receiving a system of relatively independent distributed applications that are as a rule independent of operating systems. Using of artificial intelligence systems based on the results obtained in expert systems is proposed in order to provide flexible adjustment of applications, realization of certain requirements and their change within certain limits even during the system's operation.

The paper's plan assumes consideration of the monitoring system (paragraph 2) as an automation object. Paragraph 3 considers the intelligent GIS concept. GIS construction on the basis of SOA concept is analyzed in paragraph 4. Paragraph 5 contains a version of intelligent GIS based on SOA concept. The conclusions demonstrate how the proposed technology meets the requirements of the above formed requirements for automation of multi-purpose monitoring systems.

2 MONITORING SYSTEMS

Monitoring concept and especially environmental monitoring quite often appear in specialized literature and great number of publications as well in mass media. This paper will consider environment oriented monitoring systems intended to support certain objects and/or processes. Supporting systems of different transport modes (air, marine, surface), environmental safety systems and some other can be assigned to such systems.

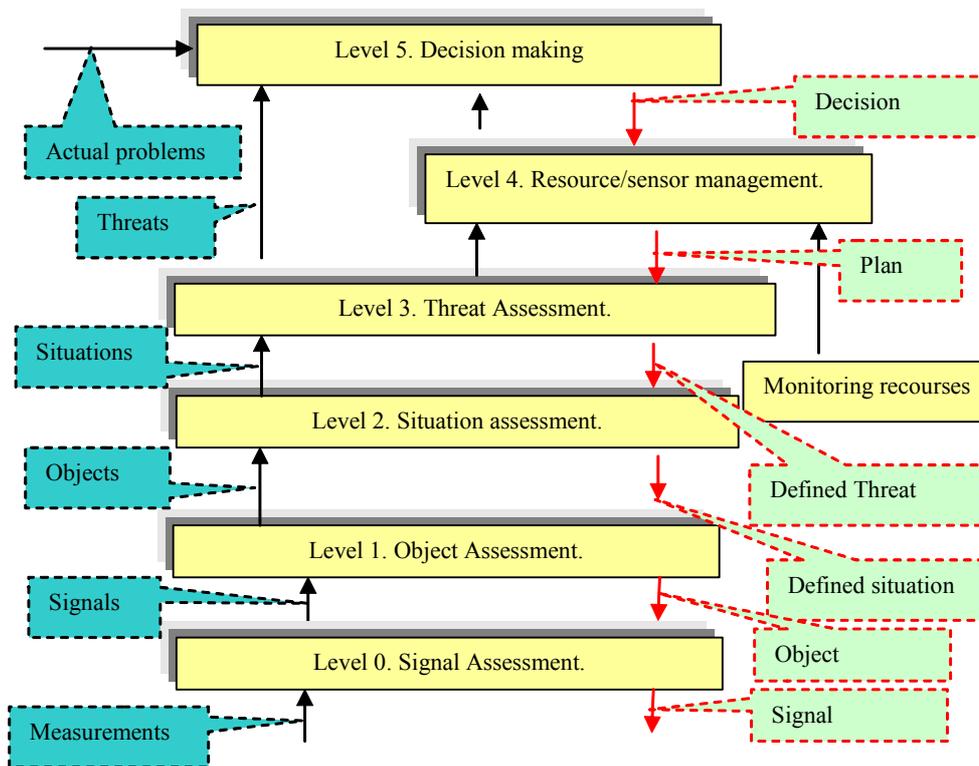
Specific but not complete characteristics of alike schemes are:

- the need to use different measuring elements for environment parameters and object parameters with given discreteness;
- the need to use diverse information of different nature from different sources, as a rule, multi-dimensional;
- the need to take decisions in a real time mode.

For the above systems the concepts like harmonization, integration and fusion of information (data) have a certain and determined sense. In this regard the main objective is an information fusion aimed to:

- reduction of data dimension (volume reduction);
- increase in accuracy and reliability of data (reduction of uncertainty);
- enhancement of data stability (correctness towards errors).

According to the main ideas of [6,8,9] a generalized model of information fusion for monitoring systems is shown in Graph 1. This model determines methodological and technical requirements for the developed computer facilities and systems including GIS.



Graph 1: Generalized model of information fusion in monitoring systems

This model became a foundation for verification of intelligent GIS development technology.

3 INTELLIGENT GEOGRAPHIC INFORMATION SYSTEMS

Challenges of the contemporary world such as nets of terrorist’s organizations, refugees and immigrant’s flows, drug traffic, ecological disasters, epidemic, computer viruses attacks – all these phenomena have a strong spatial aspect. Adequate studying of them requires spatial modelling and simulation. Purely mathematical simulation of spatial processes without visual representation (“blind” in a way), essentially decreases effectiveness of experts in discovering the patterns regulating these phenomena. For visual representation of spatial simulation on the earth-scale Geo-information systems (GIS) are suited. GIS fast evolve from the simple browsers of electronic digital maps to the complex software applications capable of visual simulation of spatial processes in the real world. As level of the GIS applications is rising and their inner logic becomes more complex the use of conventional programming languages in their development turns into a constraining factor. They urgently need means of intelligent support, such as rule-based systems, ontologies, multiagent systems and other AI techniques, especially in the web applications.

Conventionally intelligent information technologies were used in the weakly structured domains where strict mathematical theories and detailed algorithms of the information processing do not exist. Numerous GIS applications are full of such domains. However, intelligent technologies can be applied to solve their inherent problems in geo-informatics, as well as to fast simulation and/or prototyping deeply parallel processes with quite well structured theories, like target detection, with good accuracy. For instance, if you want to control distances between 100 moving objects you have to check 5000 distances periodically. How often? It depends on a current distance between every pair of objects, their current speeds and many other factors. Algorithm would be quite complex for the conventional programming languages. Second example. How to represent a process of an oil spill after a disastrous collision of tankers? Every tiny parcel of oil is moving under influence of a sea current and a wind. Movement of the whole oil stain can be represented as an assembly of parallel processes. Recent expert systems use the famous algorithm Rete[1] specially designed to monitor hundreds of thousands parallel processes. Our research shows effectiveness of artificial intelligence technologies implementation for the simulation of complex spatial processes.

An adequate simulation of the complex processes in the geographical environment, such as the earth surface, world ocean, atmosphere an other, requires an intensive using of knowledge from the different fields. Developing of computer systems for such simulation must naturally include recent geo-information technologies, knowledge representation technologies and knowledge acquisition technologies. Intelligent geo-information system for modeling and simulation can be a final goal of this development.

Intelligent GIS is here defined as a complex software product including along with the GIS itself different artificial intelligence techniques for solving complex tasks including spatial simulation. These techniques are unified in a system based on a single knowledge representation and processing framework.

Central part of the IGIS is a *knowledge base* incorporating ontology, that is a framework for representing concepts and relations between them in an application’s knowledge domain. Other part of the knowledge base is an object base, that is a storage of instances representing real objects in the application’s domain. Universal IGIS must allow loading in the knowledge base different ontologies and object bases and thereby adapt to different domain applications.

Other important part of IGIS is an *expert system* or precisely knowledge inference engine. Usually this is a rule-based system capable of processing knowledge stored in the knowledge base. Rules themselves can be stored in the knowledge base as a part of the domain description. Knowledge inference engine can solve two tasks in IGIS. The first one is traditional for expert systems and consists in giving recommendations in the complex decision making situations. The second one consists in control of objects' complex behavior during simulation. Rete algorithm mentioned above allows to describe complex parallel processes by a set of distinct simple rules and simultaneously gives highly effective computer implementation of a simulation model.

Other parts of IGIS are traditional for GIS, namely, GIS Interface that is a software component for visual representation of the spatial data in different formats along with the objects stored in the knowledge base. Further are going different sources of the geo-spatial data and software components for information processing via traditional techniques.

Right now a common practice of the academic community is to share free not only ideas but also the software used in research and development. Main reasons for using free software packages in the research projects are as follows [12]:

1. Free of charge or low cost is obviously good. Besides, this fact allows trying different systems, selecting the best one, easy change from one to another. Expensive system as a rule fastens users to itself.
2. opinion; they readily include a new functionality upon the user's request.
3. In spite of widespread opinion, open source systems possess sufficient reliability, because in a process of the development they experience a hard testing from many voluntary testers.
4. Commercial software companies also publish free open source products to have their new ideas tested, and it is naturally indeed to use them in advanced research projects.

Distinguishable place among the open source packages distributed through the Internet occupy the programs written in Java programming language. Java programs are really portable and work on different platforms directly. Besides, Java language has many special features for an integration of different programs. Taking this into account, we developed a research prototype of IGIS for simulation and modeling using three open source software products in Java language distributed free through the Internet:

1. Knowledge base developing instrument Protégé [5]
2. Expert system shell Jess [4]
3. Geo-information system developing tool OpenMap [7].

Protégé has quite useful framework for augmenting functionality on a basis of loosely coupled software modules, called plug-ins. Now Protégé has about 60 plug-ins.

To support a visual computing simulation of the different processes we have also developed another plug-in for Protégé. Main functions of this plug-in include creation of moving objects with a binding to the geographical coordinates, control of a movement of these objects in accordance with their direction and speed in real or arbitrary time scale. More complex behavior is controlled by the expert system plug-in JessTab [2], connecting Jess expert system with Protégé. This plug-in is changing the direction and speed of the objects at the required moments in accordance with the specially defined rules. To display the movement of objects on a background of a digital map OpenMap software embedded in our plug-in is used. Visual effect of the movement is created owing to a fast redrawing of the object images and using of a double buffering. Such simulation subsystem allows to stop simulation at any moment and store the positions coordinates of the moving objects in a file for a further analysis or repetition of the simulation. It also has facilities for the manual control of an object's behavior and for getting information about them. Moving objects besides images (icons) can also have text strings and/or different geometric shapes linked to them. Geometric shapes can designate, for example, regions of actions. Regions can be of irregular shape and represent either natural or artificial entities, for example, atmospheric fronts or oil spills. These shapes can move and changes also irregularly in accordance with the rules, describing their behavior. That is also under control of the expert system. This plug-in is a base for development of specific IGIS for the different application's domains. It can be downloaded from our website.

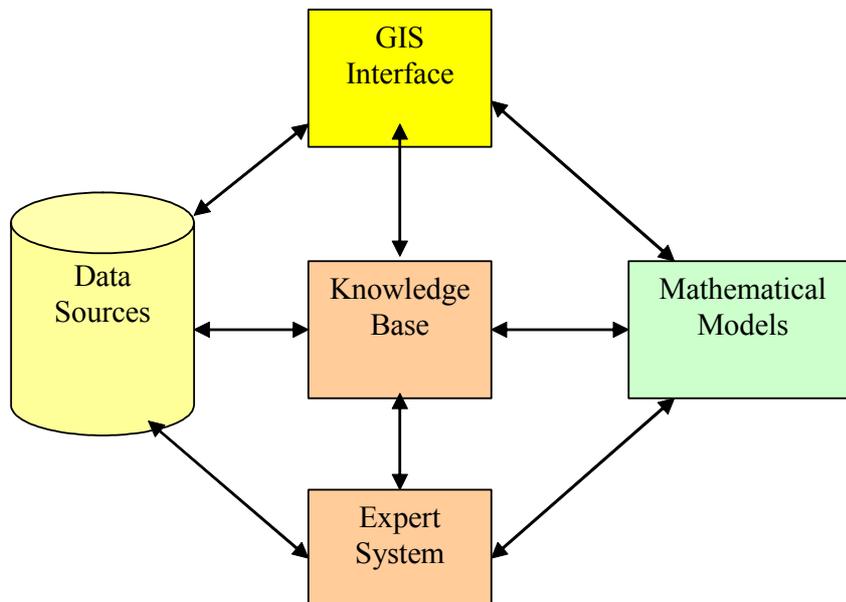
4 SOA AND GIS

Modern intelligent GIS developed as an interface for monitoring systems of different types and scales can hardly be represented as a self-contained program module. Application of intelligent GIS assumes consideration of most diverse factors, such as: obtaining at the earliest possible date reliable, variable in real time information from every possible source, presentation of information in visual form comfortable for perception. Besides, it should be understood that GIS interface can be used by hundreds of users, and in some systems the number of users can get up to dozens of thousands. And in order to meet the requirements of each of them the system has to adjust itself, to provide the required information space. Then a question arises – how should we effectively build up an intelligent GIS in order to establish productive, reliable and safe automated chains of those business-processes, integration of which is necessary for performance of our business functions? This is the Enterprise Application Integration (EAI) that has the basic IT-problems both of modern enterprises and monitoring systems for our case, and just at that spot the most effective solution tool is the service-oriented architecture (SOA) [14].

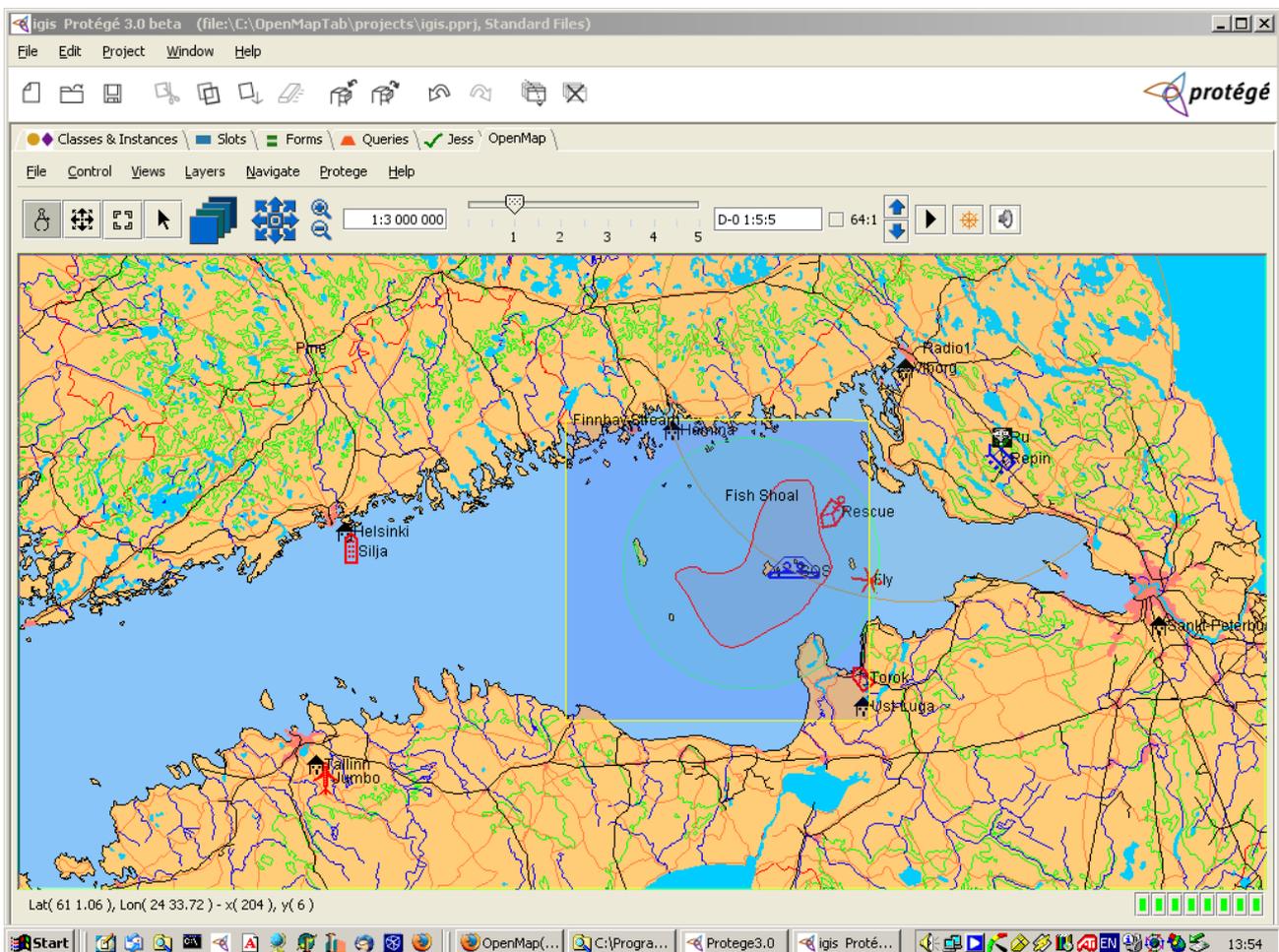
For the moment, SOA term has not been established. We can speak about SOA rather as about a technology development tendency for complicated systems than as about some technological standard. So, at present we can speak about certain backbone properties of SOA.

Architecture oriented towards services has four main characteristics:

- SOA is *distributed*. Functional elements of applications may be distributed as per the multitude of computing systems and may interact using local or global networks. In particular, Web-services enable using existing protocols (e.g., HTTP).



Graph 2: Architecture of IGIS



Graph 3: Interface of Intelligent Geo-information System

1. SOA is built using loosely-coupled interface. Usually applications are designed with a view to a stiff connection of all elements. As a consequence, the system should have an integral design, its changes during operation are problematic. Operation of components in loosely-coupled systems can be coordinated much easier and the systems can be easier reconfigured.
2. SOA is based on the *mainstream* technologies.
3. SOA is designed with orientation towards processes (process-centric) using services, which are individually oriented towards a solution of separate tasks (task-centric).

Thus, from functional point of view, intelligent GIS may be ultimately considered as a combination of interacting services, and this combination of interacting services can be specified by the term – service-oriented architecture.

A component model consisting of separate functional modules of applications called services and having certain as per general rules, interfaces and mechanisms of interaction is called: **Service-Oriented Architecture (SOA)**.

SOA should correspond to the following requirements applied to modern state of business relations and information technologies, as well as tendencies of their mutual development:

1. maintain existing information systems and their joint effective application;
2. provide implementation of integration of different types:
 - *user integration* – to provide interaction of intelligent GIS with a specific personified user;
 - *application connectivity* – to provide interaction of applications on the intelligent GIS interface level;
 - *process integration* – integration of business-processes;
 - *information integration* – integration aimed to provide information and data availability;
 - *integration of new applications (build to integrate)* – integration of new applications and services into existing information systems.
3. provide consistent implementation of newly created and migration of existing information subsystems;
4. be provided with standardized technological supportability for realization, as well as with tools for development that can jointly represent optimal opportunities for repeated usage of applications, implementation of new and migration of existing information systems;
5. allow realizing different models to construct new information systems such as portal solutions, grid-systems and on-demand systems.

The present level of SOA development proves that the above requirements, in one or another respect, are met.

Over the last years some other construction technologies for distributed information systems were introduced, e.g., CORBA and DCOM, but solutions on their basis are noticeably loosing when compared with SOA especially in regard to such technologies as the information system development and implementation cycle, possibilities to integrate heterogeneous systems, etc.

Along with business reasons for extinction of previous distributed information systems' construction technologies there existed another technological reason of similar importance: these technologies had not achieved the required maturity level. They were promoted only by individual companies, and that restricted their expansion, no standards and technical documents describing application principles for these technologies and accepted by worldwide IT-community were developed.

During development of intelligent GIS on the basis of SOA, the following methodological and conceptual solutions and conclusions were also taken into account, e.g.:

- Open-source methodology;
- Application of generally accepted and frequently used technologies and standards: XML, HTTP, TCP/IP, SOAP, BizTalk [11];
- The offered solutions are being at the maturing stage that is required and sufficient to be successfully and sufficiently applied by a large number of ISV (Independent Software Provider) all over the world.

5 INTELLIGENT GIS ARCHITECTURE ON THE SOA CONCEPT BASE

A number of terms was specified with respect to intelligent GIS in order to form intelligent GIS architecture on the basis of SOA.

Service – a resource realizing business-function that has the following properties:

- it is retrievable;
- it is determined by one or several distinct technology-independent interfaces;
- it is loosely coupled with other similar resources and can be called through communication protocols providing a possibility for interaction between different resources.

Service-Oriented Architecture – this is an architecture of applications, where all application functions are independent services with clearly determined interfaces that can be called in the required order in order to form business-processes.

On the basis of the above determination the following intelligent GIS architecture in the basis of SOA concept was developed that is presented in Graph 4.

The center link of intelligent GIS is a tool intended to develop ontologies and PROTÉGÉ knowledge data bases. PROTÉGÉ is an ontology editor, on the one hand, and, on the other hand, a storage for class instances used for monitoring classes. PROTÉGÉ architecture is shown in Graph 5.

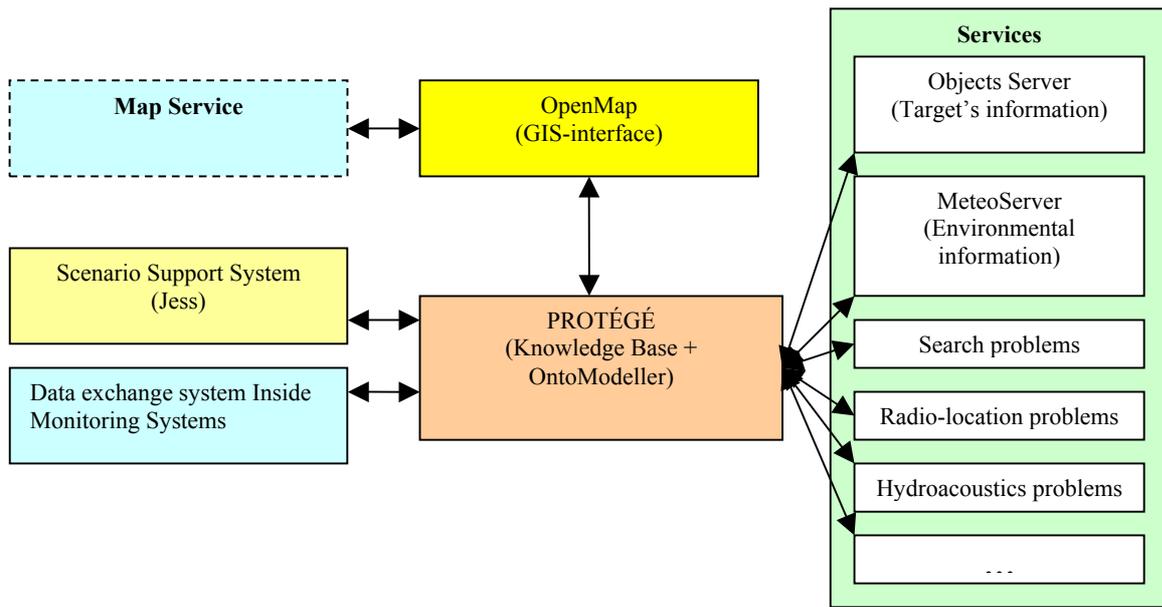
PROTÉGÉ is closely interacting with a program component of visual representation of OpenMap cartographic information. This component allows displaying the data contained in different formats, e.g., S57, VPF, etc.

Cartographic information update service is an instrument to maintain cartographic information in the actual state.

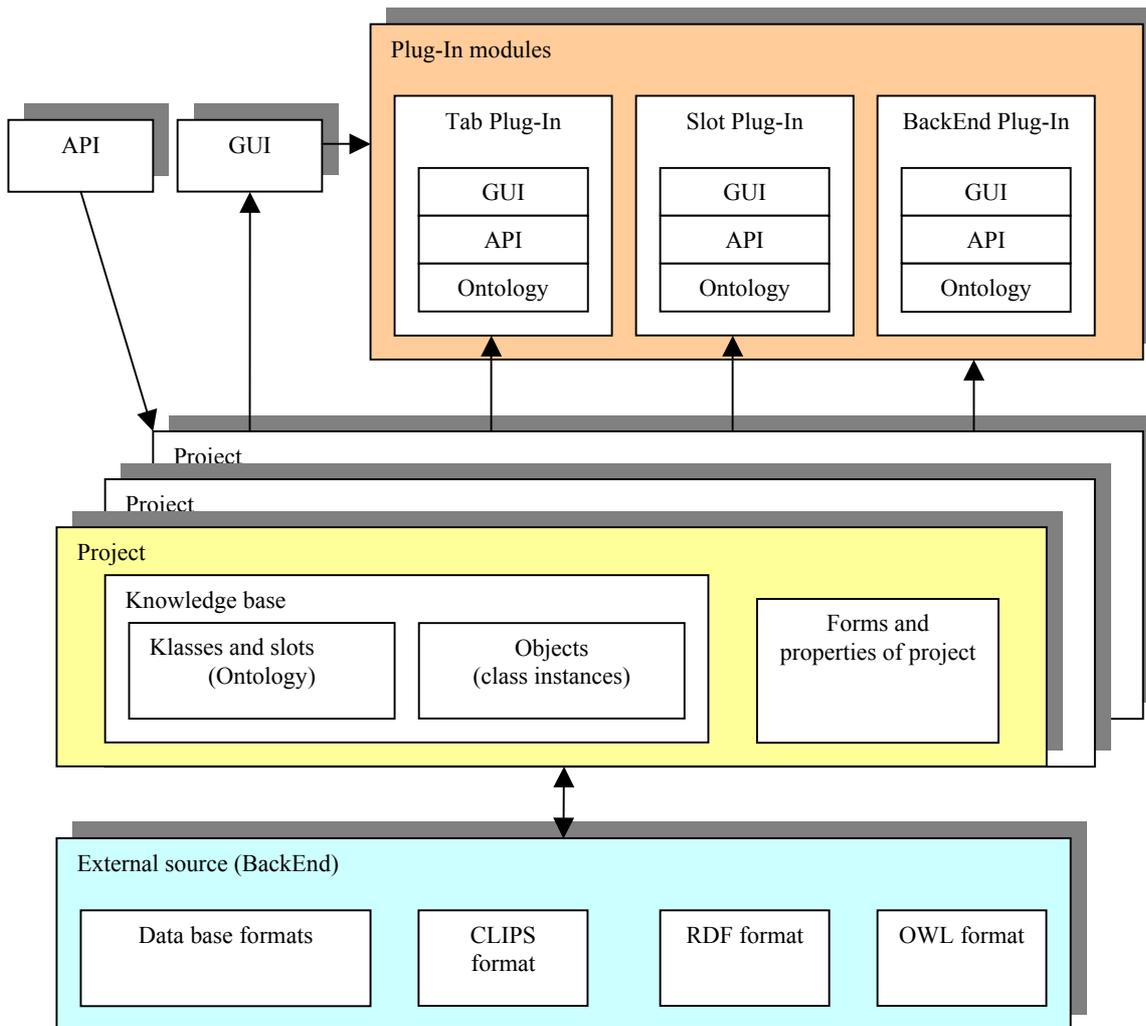
For instance, a user upon a receipt of a notification concerning the fact that cartographic information needs to be updated addresses this very service and receives information an updated information to be used in GIS-interface.

Service of information exchange between interacting monitoring systems or interacting subsystems provides exchange of documents and/or data in XML format as per the current situation.

Services such as visual libraries of functions, tasks of search that are designed for model support of decision making. The set of such services can vary depending upon the type or class of monitoring system.



Graph 4: Intelligent GIS architecture on SOA concept basis



Graph 5: Potege architecture

6 CONCLUSIONS

The method of intelligent GIS development proposed in the paper for multi-purpose monitoring systems can generally satisfy, the above stated requirements:

- easy and clear data and information access.
- smart and fast modification of the system's obsolete applications;
- quick integration of new applications into the work system;
- data standards and formats, and information support;
- reuse of software code and other resources;
- dynamic reconfiguration of the systems without new development and/or recompilation of the project on the whole;
- possibility of the IGIS operation on a separate PC, LAN and global networks.

The program system developed with participation of the authors of this paper can possibly be considered as a case study. More detailed information is available at: <http://niggis.iias.spb.su> The core of the system is formed by the intelligent GIS incorporating along with traditional GIS-technologies the following ones:

- A technology of ontology visual development for monitoring systems on the basis of Protégé-2000 using OWL;
- System of data integration from different sources (World Meteorological Organization, S57, VPF data formats, etc) and their display on the basis of OpenMap;
- Open development technology of expert systems on the basis of rules and objects using CLIPS and JESS shells;
- Open technology for presentation of knowledge on the basis of ontology using instrumental means of Protégé-2000.
- Advanced possibilities of intelligent GIS:
 - visual development of classes and objects of monitoring systems on the basis of metadata concept;
 - visual development of action scenarios of objects in geo-space environments;
 - playback of scenarios for object actions in real-time and indefinite scale of time with visual display in the form of signs at the background of an electronic chart;
 - presenting recommendations to decisions making persons in the process of the scenario playback during the investigative design of monitoring systems, business games, situation analysis and training of users;
 - easy scalability (local PC, LAN and global networks).

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