General Collaboration Architecture to Work with Geographical Information Systems

R. Quintero, M. Torres, M. Moreno, C. Carreto, and G. Guzmán

Geoprocessing Laboratory-Centre for Computing Research-National Polytechnic Institute, Mexico City, Mexico
{quintero, marcomoreno, mtorres, gguzmanl}@cic.ipn.mx, ccarretoa@ipn.mx
http://geo.cic.ipn.mx

Abstract. In the present work, we propose a collaborative-application to the National Center of Disaster Prevention in Mexico (CENAPRED), which is focused on helping in the decision making process and the tasks for preventing natural disasters, related to "Laguna Verde" nuclear plant. This application coordinates the activities of External Plan of Radiological Emergency (PERE) that has been generated for this purpose. In addition, the application is based on a Geographical Information System (GIS) into a collaborative architecture to support the interaction from several entities, which work with special training groups in a virtual reality environment. The architecture consists of a collaboration model and it generates a schema of components to find out the independence and standardization of the system so that it can be implemented in any GIS-platform. Moreover, we present the architecture to convert non-collaborative systems into collaborative ones, without changing the original structure of the application.

Keywords: Collaborative work, Geographical Information System, Collaborative Architecture, Component-based Collaboration.

1 Introduction

Nowadays, Geographical Information Systems (GISs) are powerful and useful tools as means of information, visualization and research or as decision making applications. Recently, intelligent spatial analysis is the main need presented in the Geocomputation trends. Spatial data have an important role in this situation; many times, the information is extended at different places. The problem is greater, because the spatial data present different formats and specifications such as scale, projection, spatial reference, representation type, thematic, DBMS type, and date. For these reasons, the *heterogeneity* of the spatial data formats complicates the spatial analysis.

Other problem related to the heterogeneity in GIS is the collaboration process. This collaboration cannot be accomplished due to several GIS-platforms are totally dependents for any commercial software or environment. Up-to-date, this problem is a barrier to the users that attempt to integrate spatial data and to make spatial analysis in a collaborative way for GIS-Government.

ally, the systems and architectures of collaborative work represent important tools to coordinate group activities. With the mixture of these technologies, it is possible to solve problems related to interoperability and heterogeneity of the spatial applications.

Up-to-date, the appearance of global networks such as Internet and Intranets improve organizational process to allow a better performance of the applications. Recently, some solutions or collaborative tools (independent of the GIS-architecture), are very limited. These solutions attempt to solve particular problems, some examples are shown in [3][4][6][9][10][11]. Other works related to the research integrate workflow solutions and collaborative tools finding group consensus, but it is not a global solution for the participation of multiple users.

In this work, we present an architecture to solve a particular case of study, according to the subject domain specified. Probably, this architecture can be general for any GIS that provides collaboration, cooperation services to multiple users. The case of study of this work is focused on implementing a GIS to support simulation, training and execution processes related to prevention disaster plans (PERE). These plans describe the actions that the specialists must perform in the case of radiological emergency is presented; they consider several actions to guide such as population evacuation, emergency routes, communication and infrastructure available, etc.

PERE is applied to "Laguna Verde" nuclear plant in Mexico. Therefore, the main goal of this work is to provide a solution for this scope and also defines a standard collaboration-architecture to any GIS.

The rest of the paper is organized as follows. In Section 2 we present the case of study. Section 3 describes the problem solution to the case of study and also the problems that represent to implement collaborative aspects. A general architecture for any GIS to provide collaboration capabilities is shown in Section 4. Our conclusions, future works and possible applications are sketched out in Section 5.

2 Case of Study

Nowadays, the activities involved with the External Plan of Radiological Emergency (PERE) [7] are made-up with several efforts of different Mexican Government Institutions (they are denominated as *task-forces*) such as: Army (SEDENA), Interior Ministry (SEGOB), and Navy (SEMAR) among others. Recently, these tasks are performed using a great number of human and economical resources when training exercises and practices on field are carried out. Although certain procedures have been developed and defined in PERE, the actions are very difficult to realize, because the procedures consume very much time and they are complicated. Therefore, it is necessary to count on a computational application that allows helping the process of decision making and optimizing the used resources.

At the moment, exercises of PERE with a degree of acceptable trustworthiness are made periodically. Nevertheless, there are not statistical records that allow comparing the results and progressing obtained at each one of the exercises. For instance, when the training exercise is finalized is not created a digital cartographic registry that describes the trajectory of the *task-forces* (TF) involved, as well as the parameters or variables used in that training exercise.

On the other hand, the dispersion information of radiological pollution agents used during the training is generated in independent program called RASCAL. Therefore, it is necessary to integrate these data by means of a central application so that it can facilitate the manipulation of the information and link it with the spatial data to modify the conditions during the training exercises.

Up-to-date, PERE does not count on simulations that allow observing the displacement of the TF. Also, the procedures are performed by the human experience and the operations are executed in a manual way to solve any task of the training exercise. Additionally, there are not tools that offer a support to provide alternative solutions to obtain maps for evacuation routes and other needs to the users.

The information used in PERE, it is visualized in two dimensions and analogical maps. For this reason, other aspects cannot be contemplated and distinguished. For instance, the topography of the land is an important point of view to carry out the work of each TF.

According to this, it is necessary to find out pedagogical and technological strategies that act with new informatics means together creating an environment of learning with reality. It will allow the interaction of several TF simultaneously in a same virtual scenario. It is important to consider the possibility that a single TF can execute a simulation without the operation of the other TF.

In this proposal, we present the SIGES-PERE application to aid in some tasks related to the External Plan of Radiological Emergency of Laguna Verde Nuclear Plant. The solution is oriented towards the development of a GIS, which will be able to make three fundamental tasks: *Simulation*, *Training* and *Execution* modes.

The *Simulation mode* is the automatic generation of disaster scenarios, with characteristics generated randomly from a spatial database of risk situations. Also, the system when working in this mode, will take the correct actions to solve the contingency based on the corresponding procedures manual.

The *Training mode* as in the *Simulation mode* generates disaster scenarios. Nevertheless, the decisions will be taken by different entities involved in the decision making process. In this way, these entities will practice the previously studied procedures when interacting with the SIGES-PERE.

The *Execution mode* will serve to provide pursuit to the situation in the context of a real emergency. In this operation mode, the disaster scenario will be defined by the user administrator. The decisions will be taken by the commanders of the TF.

In all cases, the information will be visualized in graphical way (spatial data). Dynamic data will appear in real-time over the cartographic information. These data will represent relevant information related to the situation of the scenario such as location of the TF in field, conditions of the population, state of the shelters, and so on.

3 Problem Solution

In this Section we present the solution applied for the problem described in Section 2. Such solution is presented in two parts; first the modeling of the case of study and the architecture proposed to implement the model.

3.1 Operation Modes

SIGES-PERE involves the use of a cartographic base in a digital format; these formats will be raster and vector, which will be used to locate the spatial position (geographic reference) of all the elements involved in PERE.

Therefore, it is necessary to generate the set of rules that must be followed when executing PERE. These rules will allow knowing the behavior of all the operations that will be carried out into the application. In addition, we have to define the conditions that take part in the analysis, such as: climatologic properties, infrastructure, density of population, land use, among others. It implies that the set of rules of PERE and the conditions of the environment will be stored in a *knowledge-base*.

The raised solution is based on three operation modes, which are described as followed.

3.1.1 Simulation mode

In this operation mode random scenarios of disaster will be generated and the system automatically will make the decisions that consider advisable. The scenarios will be generated according to the group of conditions that could be presented. By using the knowledge-base, the catalogue of scenarios defines the values for the variables of risk conditions. The decisions will be carried out considering the procedures defined in the knowledge-base. Next, the general processes that compose this operation mode are described in Fig. 1.

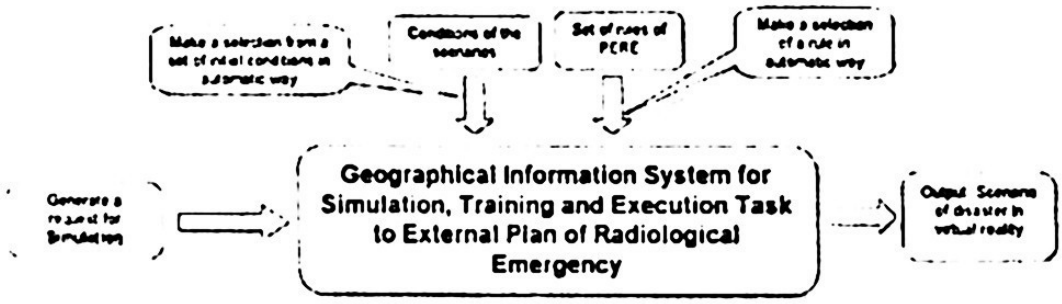

Fig. 1. Processes of the simulation mode into SIGES-PERE

3.1.2 Training mode

In this operation mode the scenarios of disaster will be generated in automatic way, like in the simulation mode. But, in this mode the decisions are taken by the TF. In sense, simulation training exercises of PERE will be able to be made. Nevertheless, the decisions of the operation (activity) to follow could be modified by each TF in a manual way, according to the presented/displayed situation. In addition, the conditions of the scenario could be modified in the moment of executing the maneuvers, which allows providing pursuit to the risk event. This mode will be possible to observe the displacement and location of the TF, as well as the state of the infrastructure and the displacement and/or location of the population (see Fig. 2).

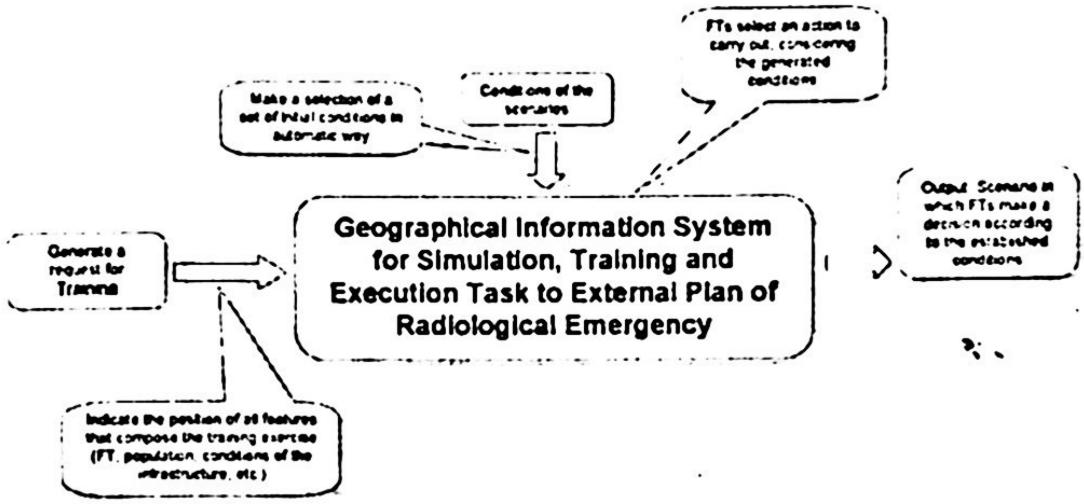

Fig. 2. Processes of the training mode into SIGES-PERE

3.1.3 Execution mode

This operation mode will be used to provide pursuit to the situation in the context of a real emergency. Since the conditions, decisions and pursuit are made-up by each unit of the TF. These elements generate in the system the real scenario of the disaster and it will be performed with base in the field readings (see Fig. 3).

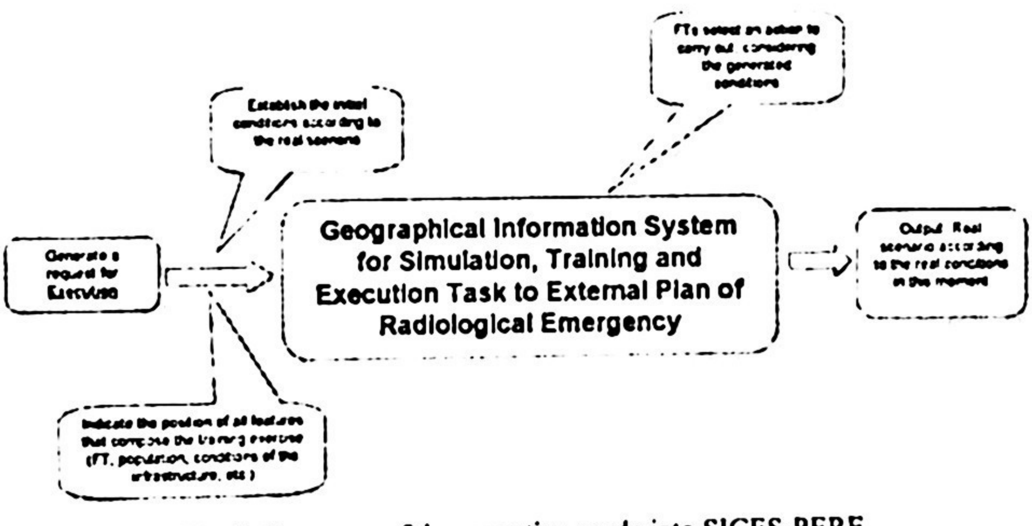

Fig. 3. Processes of the execution mode into SIGES-PERE

3.2 Architecture of SIGES-PERE

The architecture of SIGES-PERE is composed by eight fundamental tiers. This application will be installed within the Primary Emergency Control Center (ECC). On this application, each TF will count on an independent terminal in which they will be able to execute the SIGES-PERE application to interact with the rest of TF, by means of a Local Area Network (LAN). These tiers are grouped in two categories: the category of storage and the functional one.

The *category of storage* is composed by the knowledge-base and the spatial database. The knowledge-base is used to store a catalogue of accidents, which will be defined by the institutions that take part in the prevention of any disaster. Additionally, this knowledge-base will store the environmental conditions that can appear, as well as the set of rules that describe PERE. The spatial database will store the geographic and attributive data of the area, helping in the interaction of the scenarios by means of the development of a base-map.

In the *functional category* are grouped the modules of *Simulation*, *Training*, *Execution* and Spatial Analysis. Here, it is possible to find all the processes that belong to the data manipulation of a virtual scenario, as well as the digital cartography.
Similarly, it contains an administration mechanism of input and output processes denominated *GIS Engine*, which will be in charge of handling the requests performed from each entity. The *communication system* sends and receives the data trough a communication protocol. The retrieval process of spatial data is performed by ArcIMS, which will be used as a user interface for every TF. In Fig. 4, we depict the architecture of the SIGES-PERE application.

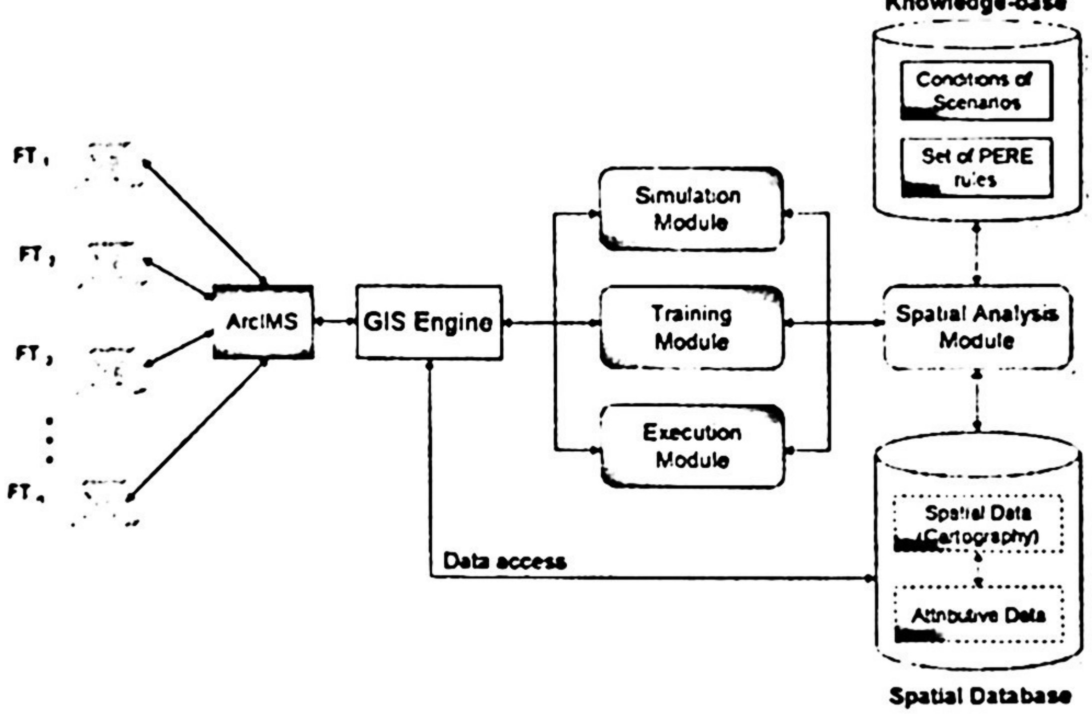

Fig. 4. Architecture of SIGES-PERE

Moreover, in Fig. 4 we appreciate that every TF makes a request to the system by means of ArcIMS. This component sends to GIS Engine the request to access to the spatial database and to retrieve the scenario with the base-map. According to the situation, that has been proposed by the administrator, the scenario is retrieved to the TF and it can operate in any operation mode, which is considered by the administrator when he has determined the training exercise. All the processes are computed by the GIS Engine and the spatial analysis depends on every situation. The values of parameters and conditions are established by the knowledge-base according to the scenario proposed to the practice.

3.3 Collaborative Aspects

In the model presented above there are not modeled any collaborative aspect nor implemented. Nevertheless, it is intuitive that there must be collaborative entities due to the TF are working together in a network environment.

It is necessary to count on a set of elements that allows realizing the collaboration, between users and TF resources, in a natural and intuitive way. Also, such elements must be independents of the TF as well as the operation models of the system. On the other hand, an important technical requirement is that such elements to be also independents of the application to use them directly in other applications.

There are some works made about resolve such problems [1][2]. However, they do not provide a general architecture to collaboration (i.e., it is necessary to implement one for each case of study). Moreover, in these works are not provided *interoperability* between different collaborative applications. Applications that are not necessarily GIS ones. For example, it is not possible to make a GIS interoperates with a Collaborative Virtual World (CVW). Then, we propose an architecture to build collaborative applications that fulfill the constraints outlined above.

4 Architecture of Collaboration-GIS based on Components

As we mentioned on the last section, we propose an architecture for implementing collaboration services into a GIS. We have established several goals to achieve this collaboration:

- To allow performing the collaboration in an intuitive and natural way among different users and entities that form the TF.
- Independent architecture from the task of TF and the operation modes related to SIGES-PERE.
- Independent architecture from the application to be able to use in other applications.
- To provide interoperability aspects to the architecture between different types of applications, which are not necessarily GIS.

4.1 Collaboration Model

The collaboration model is composed of three main features:

- **Task-Forces (TF).** They are defined as the different existing users that interact with the GIS. Each one of them defines the actions, which can take with other TF inside the SIGES-PERE.
- **Collaborative Geographical Information System.** It is defined as any GIS being added; it is composed by a collaboration interface.
- **Resources.** They are defined as the elements of interaction with TF. They can be static or dynamic features of interaction according to the action that represent. These resources are used to access the meaning of other elements like vehicles, shelters, etc.

In our proposed model there are interacting groups of users belonging to different TF, and groups of resource services. We will denote *F* to the group of all existing TF inside the SIGES-PERE and will denote *R* to the group of all resources. The capabilities of work and collaboration of any user and the way that they interact is defined by the TF. In other words, when a TF is defined inside SIGES-PERE, its functions must be specified according to the type of TF. Moreover, at this point the set of possible interactions among TF is defined.

Each one of TF partially describes the form that it will interact with others TF defining a set of collaborative interfaces, which provide access to the services.

To establish all possible interactions between the elements of the GIS, we have considered the proposal that is described in [2]. We use a *directed graph* that is shown in equation (1).

$$G = (V, E) \text{ where } V = F \cup R \text{ and } E \subseteq F \cup R \times F \tag{1}$$

Each edge on *G* defines a particular collaboration; this allows a user to collaborate in a particular way depending on the role of its counterpart. In other words, it has access to a set of different collaboration actions.

For instance, if a CENAPRED user needs to collaborate with a SEDENA user, it is necessary to send a collaboration request to the SEDENA user, which allows both users to exchange their collaboration actions; this collaboration is shown in Fig. 5. Probably, the CENAPRED user can ask information related to the localization of certain group of soldiers, and SEDENA user responds according to the information of the SIGES-PERE.

By using this schema, it is possible that SIGES-PERE defines different types of collaboration among diverse TF. At the same time, it is indispensable to integrate several types of TF, and each one can define the interaction mechanism with other features of SIGES-PERE.

4.2. Architecture of Collaboration

In this section, we describe the proposed architecture for implementing the schema of collaboration in the SIGES-PERE application. The architecture is based on the *Body-Soul* model, which is described in [5]. This model presents a flexible architecture oriented towards to implementing collaboration schemas of different elements into the systems.

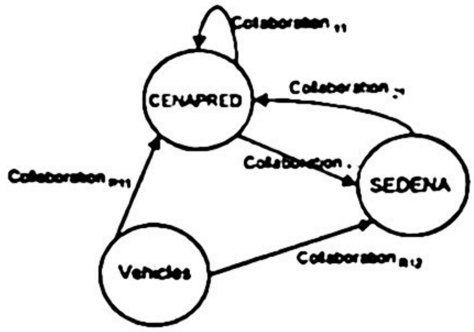

Fig. 5. Collaboration between TF and resources

Therefore, the architecture is composed of three main features as they are described as follows:

1. **Input/Output Information Component (IOIC).** This component is installed over any instances of SIGES-PERE. Its function is to handle and allow that the generated data can be standardized to be distributed for the collaboration interface.
2. **Collaboration Interface.** The interface is in charge of maintaining a repository of references to generate objects that represent the TF. In addition, it administrates the collaboration and maintains the state of the collaborating features.
3. **Distributed Objects (TF).** These objects represent to the TF. They maintain the reference to the collaboration interface and allow defining collaboration entities.

As we can observe in Fig. 6, a TF object is generated per each TF, which directly interacts with a reference located on the collaboration interface. It administrates the references of all the TF defined. The collaboration relationships between the TF are performed by means of the collaboration interface, it is not necessary to consult the SIGES-PERE to obtain the information requested, it is made-up through the IOIC, then it will return the information requested to the collaboration interface to handle and distribute it to the TF that are collaborating with it.

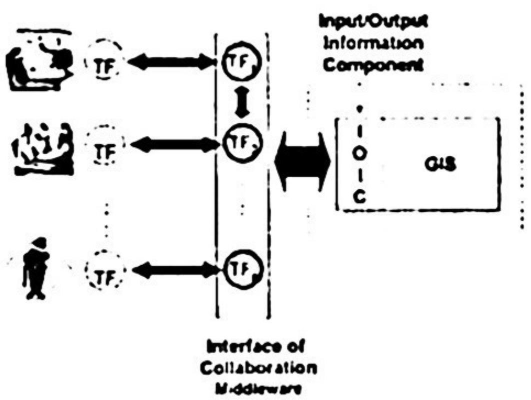

Fig. 6. Collaboration architecture for SIGES-PERE

The architecture provides interconnectivity services for the users. The system provides services of any collaboration type such as collaboration tools (forums, boards, etc), decision making systems, workflows, smart functions, and so on.

Our proposal consists of an architecture that has a component-based schema. Although we applied this architecture to the SIGES-PERE, it is possible to use it for any GIS and also for any information system. The development of architecture components has been made integrating aspects of free software using tools and open source, which are viable option to provide us the opportunity of reducing the cost of the solution.

The SIGES-PERE has been implemented in C++. The collaborative model has been developed in Java and RMI (described in [8]). We made the integration using JNI, but future versions we will use C++/CORBA to implement the collaboration modules.

4.3. Preliminary Results

The purpose of this work is to translate a common GIS-application into a collaborative one. By applying this architecture, we have converted the GIS-application, which is called SIGES-PERE into an embedded-collaborative system. This application solves the problematic outlined in Section 2, and it integrates the collaborative aspects mentioned in Section 3.

SIGES-PERE is a GIS, which contains common functions such as: Spatial Visualization Operations (Pan, Zoom In, Zoom Out), Spatial Overlapping Operations, 2D and 3D Representation Operations, Virtual Flights and an efficient user-friendly interface to the clients. In Fig. 7 is shown the main window of SIGES-PERE.

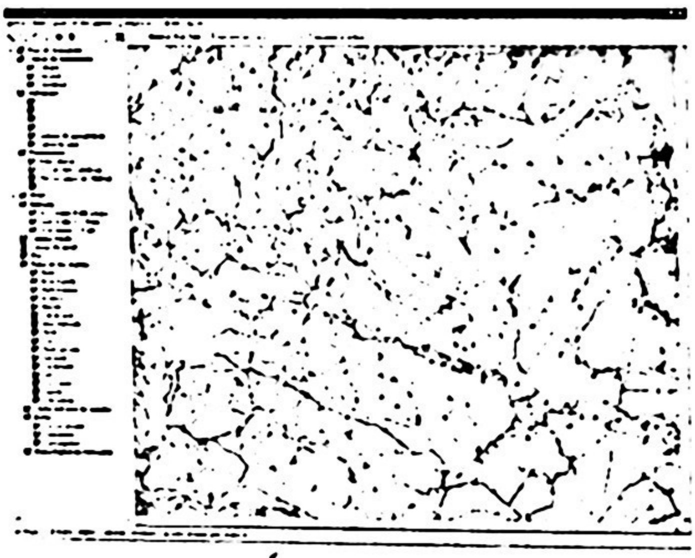

Fig. 7. Main window of SIGES-PERE

The collaboration model is applied over the system; this provides a collaboration interface for users of distinct TF. The implementation is still in the test phase; however, it allows users to collaborate with a restricted number of tools. As we mentioned, one of the goals of the architecture is to maintain the independence of the application. Due to this, it is necessary to implement the collaboration interface for each service provided by SIGES-PERE.

In the implementation, we are using distributed objects to make collaboration. The distributed objects are implemented in Java, using the Java RMI platform. In future versions, we will use C++/CORBA, because all components that we use to make spatial analysis are developed in this language. So, the current version uses JNI to communicate Java with the application wrote in C++.

Moreover, we have made interoperability tests between SIGES-PERE and a Collaborative Virtual World defined in [1]. As a result, users can interact within the virtual world exchanging messages and resources.

5 Conclusions and future work

This work presents a solution to help in the tasks of the PERE, as well as the training of the TF that are in charge of executing these activities in field. The system allows integrating dispersed data within a collaborative GIS-environment in which all the TF can use the data when they need. Also, the TF can interact with each other to optimize resources and avoid duplicate tasks.

Moreover, we present an architecture to convert non-collaborative systems into collaborative ones, without changing the original structure of the application. This is made by adding components to provide the collaborative behavior to the IO system.

With this approach, it is possible to develop the collaborative system independently of the particular system. An advantage of this; is the possibility of changing the collaboration policies without modifying the system ones. Just, it is necessary to change the roles that each user plays in the collaborative environment. Another feature of the architecture is to provide the mechanism to define the collaboration policies. It is made in a formal way by means of a *directed graph* in which all roles and collaborations are defined. With such definition, it is possible to assign permissions and restrictions to specific roles independently of other ones, and without the use strict schemas as user levels or hierarchies.

On the other hand, with the architecture introduced, it is possible to interoperate with other applications using the same architecture. It is performed by means of the implementation of distributed objects that provide us access to the resources in each collaboration system, and that can be accessed by any other distributed object that knows its interface (defined by the architecture). In this line, a future work is related to integrate the architecture a feature of *service-discovery*. It can improve the interoperability between collaborative systems, due to by means of this *service-discovery*, it is not necessary to know neither the precise interface nor the type of application to interoperate with it.

Another work is to define security schemas that allow users being sure about the confidentiality, integrity, service availability, access control and no-repudiation, because some TF will be far from the conflict zone. For example, one of the TF is the Federal Government represented by the President and its cabinet. So, the security system is very important.

In future works, we have considered to perform some changes in the implementation to migrate the collaboration modules from Java RMI to C++/CORBA. With this change, we can guarantee a multi-platform focus.

Acknowledgments

The authors of this paper wish to thank the Centre for Computing Research (CIC-IPN), General Coordination of Postgraduate Study and Research (CGPI), National Polytechnic Institute (IPN) and the Mexican National Council for Science and Technology (CONACYT) for their support.

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