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FACILITATING UNIFORM INTERCOMMUNITY NATURAL RISK MANAGEMENT THROUGH METADATA FOR HIGH-LEVEL GEOGRAPHIC AGGREGATIONS

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1. INTRODUCTION

Natural risks are those derived from the occurrence of a natural phenomenon that may cause damages to human beings or properties. Some examples could be landslides, avalanches, floods, forest fires, earthquakes, and different meteorological phenomena, etc. According to studies of the International Federation of Red Cross and Red Crescent Societies, the number of lives lost due to natural disasters has been decreasing over last several decades in industrials countries, largely thanks to advances in disasters indication and warning capabilities. However, costs derived from natural disasters have risen, particularly because of the combined result of increasing urbanization and increasing complexity of our infrastructures. In addition to these economic costs, it should be also considered the social costs derived from aspects like citizen un-protection and environment degradation. On the other hand, revolutionary advances in the areas of communications, remote sensing and computation capabilities now enable the sharing of information as never before. It is largely accepted [1] that the potential for reducing natural disasters costs must be based on the better application of information technology, i.e. integrating specialized knowledge with information and interconnectivity infrastructures.

The level of damage caused by natural risks may even increase if the geographic area affected involves more than one political region with responsibilities and resources in this theme. Communication and coordination of different administrations, compatibility and interchange of resources, and cooperative vs individual work are some examples of problems derived from the special condition of intercommunity areas of natural risks. The management of these special problems can be done with tools which has been designed over the idea of information sharing and interoperability of systems. In general terms, and as it is cited by GDIN (Global Disaster Information Network) [2], the objective is to facilitate "the adequate information, in the adequate format, to the adequate people, in the adequate instant". More concretely, risk management tools should facilitate its labour to people responsible of risk and natural disaster management in an adequate decision making, enabled by information availability and specialized functionality. Those tools would serve for decision making in crisis management as well as for planning of prioritized actions in order to prevent natural risks.

Tools would be able to visualize and/or handle geographic information. That is thought to be realized by means of the set-up of an interconnected distributed system. That is to say, Internet will be considered as a main artery for information flow and a set of servers from different services or organisms which should be update and serve its information which would give and will take resources from the network. To do this, it is necessary to have appropriate descriptions of the geographic data based in using international standards for geographic metadata. This metadata contains several terms that allow search functions through the use of geographic information catalogs. However, to give data that represents whole intercommunity areas can be done only by integrating partial results from different providers. Current metadata standards are not be able to manage these special situations.

This paper presents an approximation for the development of natural risk management tools based on the integration of resources from each one of the communities that participate in the intercommunity area. Additionally, the problem attached to homogenize the view of multiple community resources together will be solved by defining metadata for high-level aggregations grouping those resources.

The rest of the paper is structured as follows. Next section presents the risk management scenario. After that, it is shown an architectural view for a risk management system in this scenario. Following sections introduce the reader to geographic catalogs and metadata concepts. Later, metadata to support high-level geographic aggregations will be explained as well as an example of use making profit of this additional support. Finally, this work ends with a conclusions section.

2. THE RISK MANAGEMENT SCENARIO

Maybe, one of the most complex zones of the European Community from the natural risk management point of view is The Pyrenees. It is a mountain range that it is among France, Andorra and Spain. Together with the Alps, it is one of the most complicated areas of the European Community in order to establish a coordinated natural risk management. In addition to the difficulties derived from the inherent nature of the mountains, there are many other problems concerning the political organization of that area: three countries with their central government responsibilities and resources, and four regions in Spain (País Vasco, Navarra, Aragón and Cataluña) and three in France (Aquitaine, Midi-Pyrénées and Languedoc-Rousillon) with their corresponding responsibilities and resources.

The area of control, in this case The Pyrenees, is considered as a whole territorial entity, whose information would be structured from massif scale to the town or municipality scale. The organisms interested in visualization or study of risk areas are numerous: Civil Defence Organisation (Civil Protection), Cadastre (Land Registry), Tourism, Roads and Communication Via Services, Environment, Industry and Energy, Councils, Sport Federations, Sport Clubs, companies and public in general. Such visualization or study requires the design of information systems, able to combine a large amount of territorial information coming from a great number of organisms or services at national, regional or local level.

In the crisis management of natural disasters occurred in the same area but belonging to different regions, geographic information tools, which are able to be used by the different administrations, will facilitate enormously (in great measure) an efficient management with the possibility to integrate services thanks to a (better) more fluent communication.

The global as well as specific consideration of information coming from different regions, not only of the spatial aspect but also of the legal and juridical aspects of natural disaster risk social treatment, will enable the detection of spatial or legal gaps, over which prioritised action lines will be designed to palliate such gaps.

3. ESTABLISHING A SPATIAL DATA INFRASTRUCTURE FOR RISK MANAGEMENT

3.1 Architecture proposed

The crucial key to develop a risk management tool for the scenario presented in this paper is the integration of large amounts of geospatial data in order to analyze and monitor in real time possible hazards in order to prevent natural disasters.

The problem of management of large amounts of geospatial data is not particular for this scenario. Geospatial data have been collected for more than 35 years and the collection speed increases quickly with new technologies in high resolution satellites, GPS, data bases, new software technologies for processing geospatial data and the increase of people and organizations which are collecting and using this kind of data. In fact, about 80% of data bases used by public administrations have geospatial references (addresses, city distributions, cartographic coordinates, etc). Geographic information has been turned into a vital element to make sound decisions at the local, regional, and global levels. Crime management, business development, flood mitigation, environmental restoration, community land use assessments and disaster recovery are just a few examples of areas in which decision-makers are benefiting from geographic information. However, information is an expensive resource, and for this reason appropriate information and the resources to fully utilize this information may not always be readily available, particularly in third-world countries. Moreover, it is not unusual to find that, even among different divisions/departments of the same organization, there is no knowledge about what data is currently available. This lack of synchronism leads into a consecutive recreation (or ordering to data suppliers) of data with similar characteristics.

One way to face with these problems is through the creation of Spatial Data Infrastructures (SDI) [3]. The main goal of this kind of infrastructures is to facilitate and enable an efficient exploitation of geographic information to the multiple stakeholders in GI market. Many national, regional, and international programs and projects are working to improve access to available spatial data, promote its reuse, and ensure that additional investment in spatial information collection and management results in an ever-growing, readily available and useable pool of spatial information throw the development of SDI.

A typical SDI is organized around a set of interoperable components, which offer their services through one or more instances of them via Internet/Intranet. Maybe the most relevant component is the geographic metadata catalog [4]. This kind of components are the solution to publish descriptions of geospatial data in a standard way that enables search across multiple servers [5], [6]. It enables users to locate the spatial data of interest. Next section provides a more detailed description about the construction and use of geographic catalogs.

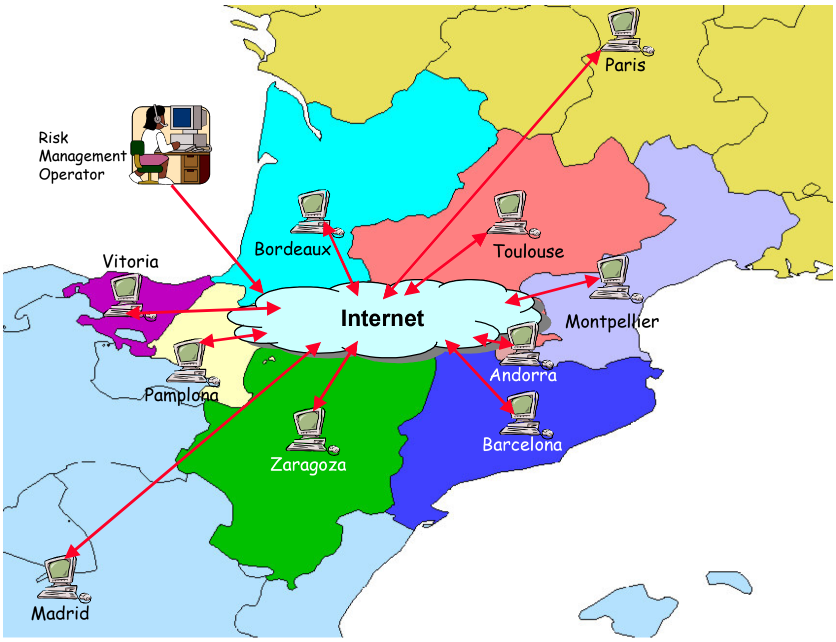

Fig. 1 Distributed resources

Another vital component to interrelate spatial data infrastructures is the Services Catalog component. In order to make accessible the catalog of an institution or to access catalogs belonging to external institutions, it is necessary to create a network of distributed catalogs. This component offers services to register and deregister catalogs. By means of this catalog, which monitors the catalogs available in a distributed network, it is possible to distribute queries among different sites.

Concerning our particular scenario, the architecture proposed is based on the concept that "each entity has the responsibility of maintaining their own data, offering the latest version of them to the rest of organizations transparently via Internet (according to the type of user)". This would avoid a clear waste of money affecting nowadays to some administrations, where georeferenced information of distinct administrative units can not be used since it belongs to systems not homologated of just why they belong to different administrations.

Basically, each one of the capitals of the communities involves in the natural risk management area of interest, and the capital of the corresponding countries, should provide a node with a Catalog Server in order to offer data created and maintenance by entities established in those cities. These components could have direct access to the information, or working as wrappers to the corresponding servers at different levels of abstraction inside the entities. Over the city nodes, there exists another abstract level that joins all of them under one unique view. This provides a flexible and easy to grow architecture that allows the development of a natural risk management tool incrementally.

3.2 Geographic Catalogs

As it has been explained before, the main objective of a infrastructure for this risk management scenario is to provide an integrated view of the resources, which are produced and available at different nodes of the infrastructure. Therefore, the first requirement for this management will to enable user or application software to find resources that exists anywhere within the distributed computing environment of the intercommunity territory. For that purpose, Geographic Catalog Servers will be set up at each entity/node of the territory as a solution to publish descriptions of the resources available. Geographic Catalogs are discovery and access systems that use metadata ("data about data") as the target for query on raster, vector or tabular data information. See next sections for a more detailed description of metadata and special metadata extensions for this particular scenario.

In order to have an interoperable distributed network of catalogs, they must conform to a standardized specification of services. One of the leading specifications proposed for catalog interoperation is the OGC Catalog Services specification [4]. This specification describes the set of service interfaces which support management, discovery, and access of geospatial information. OpenGIS provides interface implementation specifications for various Distributed Computing Platforms (DCP) such as CORBA or WWW (compatible with Z3950 Search and Retrieval Protocol).

Discovery services allow users to search within the catalog. They enable local information searching as well as distributed queries within the network of distributed catalogs. In order to implement these services, queries must be broken in portions directed to a specific compatible catalog, either local or remote. Once partial results are obtained, they are joined in order to create the final answer for the client. To make the distributed search it is necessary to have information relative to each remote catalogue as well as its syntax of interrogation. To provide this syntax, OpenGIS has defined a "Common Query Language" [4] which enables clients to write queries in a neutral interrogation language.

Management services provide functionality for the management and organization of metadata catalog entries maintained in a local storage device of the catalog, e.g. a database if metadata is implemented as a relational database schema.

Finally, the objective of the Access group of services is to enable access to items which have been previously located through Discovery services. Access to geospatial data from the consumers point of view is a part of a process that goes from discovery to evaluation, then to access, and finally to exploitation. Under the specification of OGC catalog services, the Access services are divided into two types: direct access and brokered access. The Direct Access Service provides a handle to access the data such as a pointer to OGC Simple Feature or a URL to download data by FTP. On the other hand, the Brokered Access Service provides the clients with methods to order data that will be delivered in some way by a third party component or organization outside the geographic catalog component, probably implying e-commerce transactions.

3.3 Metadata

Metadata are "data about data", that is to say, they describe the content, quality, condition, and other characteristics of data in order to help a person to locate and understand data. The creation of metadata has three major objectives. The fist one is to organize and maintain and organization's investment in data. Metadata help insure an organization's investment in data. As personnel change or time passes, information about an organization's data will be lost and the data may lose their value. Later workers may have little understanding of the content and uses for a digital data base and may find that they can't trust results generated from these data. Complete metadata descriptions of the content and accuracy of a geospatial data set will encourage appropriate use of the data. Such descriptions also may provide some protection for the producing organization if conflicts arise over the misuse of data. The second objective, as explained in previous section, is to provide information to data catalogs and clearinghouses. Applications of geographic information systems often require many themes of data. Few organizations can afford to create all data they need. Often data created by an organization also may be useful to others. By making metadata available through data catalogs and clearinghouses, organizations can find data to use, partners to share data collection and maintenance efforts, and customers for their data. Finally, third objective of metadata is to provide information to aid data transfer. Metadata should accompany the transfer of a data set. The metadata aids the organization receiving the data process and interpret data, incorporate data into its holdings, and update internal catalogs describing its data holdings.

Metadata describing resources at each node must be standardised in order to enable interoperable distributed searches across the multiple catalog servers. There are several standards describing consistently a specific geospatial data resource. Some examples of these standards are American CSDGM of Federal Geographic Data Committee [7], ISO/TC 211 draft international standard DIS 19115 [5], CEO-Recommendations on Metadata [14], or European CEN/TC 287 prENV 12657 [8]. Most of them are still pre-standards, drafts or recommendations. Although current trend is to migrate towards ISO as soon as its is approved as an international standard, the American CSDGM is still the most widely used in GIS world. It is the oldest one and has been popularized by the development of North American Spatial Data Infrastructure and its Clearinghouse project.

The fact is that all of these standards share a common core of elements (at least 40%) and it is possible to construct systems talking these different standards and enabling interoperability. In order to give an idea of the different aspects of data covered by this common core of geographic, the following sections could be mentioned. An identification information section contains basic information such the name of the data set, references to the originators of data, what geographic area it covers, keywords, status of data or information about access and legal constraints. A data quality section usually describes how good are the data, details positional and attribute accuracy, or explains the process and sources that originated the dataset. Sections like Spatial Data Organization and Spatial Reference system compile the specific characteristics of pure spatial information, that is, the spatial data model that was used to encode the spatial data (vector, raster, …) or other possible methods for indirect georeferencing (street addresses, postal codes, …) and information about the spatial reference system used, e.g. geographic coordinates (longitude/latitude), a map projection or a grid system. An entity and attribute information section informs about what geographic information (roads, houses, elevation, temperature, etc.) is included and the encoding methods (codes used and meaning, …). Finally another basic section is distribution information i.e. who distributes the data, what formats are used, availability and price of data and so on.

Apart from the standard, metadata cataloguing systems must support (recognize) three forms of metadata [3]: the implementation form (within a database or software system), the export or encoding format (a machine-readable form designed for transfer of metadata between computers), and the presentation form (a format suitable to viewing by humans). For the last two forms, there is a general consensus about the use of extensible Mark-up Language (XML). First, it includes a capable mark-up language with structural rules enforced through a control file (Document Type Declaration, or DTD) to validate document structure, i.e. conformance with a metadata standard DTD. And secondly, through a companion specification (XML Style Language, or XSL), an XML document may be used along with a style sheet to produce flexible presentations or reports of content according user requirements. The majority of metadata cataloguing systems tend to exchange metadata in XML conforming to different standards on user demand, i.e. providing ISO, FGDC geographic metadata views as well as more generic standards like Dublin Core (minimal description of resources, whatever their nature, for discovery purposes).

Finally, it must be mentioned that, whatever the metadata standard used, all of them allow specific extensions or profiles to represent the special context where data is produced or used. In this case, concerning the particular requirements of this risk management scenario, it seem clear the necessity of supporting a higher level of metadata enabling a homogenous appearance of existent resources distributed in each node of the infrastructure. That is to say, at least one central geographic catalog of the infrastructure must contain metadata entries providing an aggregated view of individual resources with equivalent semantic content, e.g. an aggregated view of vegetation index resources, an aggregated view of ortho-photography and so on. Next section faces the problematic and extensions proposed in order to support of the concept of aggregations within metadata.

4. METADATA TO SUPPORT HIGH-LEVEL GEOGRAPHIC AGGREGATIONS

The problem of how to describe aggregations within metadata is an important issue in new metadata standard proposals [5], [9]. As long as catalog search services is concerned, it is accepted the relevance of presenting the user an aggregated view of what it is available instead of an infinite list of results [10], e.g. similar scenes/data available at several instant times. In general, two main types of aggregations are distinguished in those standards regardless of terminology: *single type collections* and *multiple type collections*. A single type collection represents the aggregation of multiple data granules from a single source, where *granule* is defined as the smallest data unit in an archive that a user can order without requiring special processing to generate it. For instance, a collection of all monthly average land surface temperatures or a mosaic of digital ortho-photography is considered as a *single type collection*. On the opposite, the second type of aggregation (*multiple type collection*) compiles data layers or components coming from different sources in order to perform a GIS study or project. For example, an study of the effects of *El Niño* and *La Niña* events on vegetation could contain TOPEX/Poseidon [11] total monthly average sea surface heights and values for the Normalized Difference Vegetation Index (a model for converting satellite-based measurements into surface vegetation types) taken from the NOAA/NASA Pathfinder AVHRR Land program [12].

In order to support these types of aggregations within metadata, several extensions to metadata models have been proposed in [9] or [5] (annex I "*Hierarchical Levels of Metadata*"). In most cases a metadata hierarchy has been established where metadata for the aggregated level maintains an association to the metadata for the component level. Usually the metadata for the aggregation defines the general objectives and characteristics and the metadata of aggregated components only revise the metadata elements specific for each part. In order to implement these approximations, it is considered that this metadata hierarchy resides on the same catalog node.

Nevertheless, what we need for this risk management infrastructure scenario is to provide an aggregated view of datasets which are not only produced at different nodes but whose metadata is also maintained at different nodes. Probably, metadata for these datasets was created long time ago and for other purposes at each node, before they are reused for this natural risk management infrastructure. Thus, it is necessary to define a new type of aggregation able to describe a joint view of data and metadata distributed in different nodes. The name given to this new type of aggregation is *high-level aggregation*.

Figure 2 shows an UML class diagram with the different types of aggregations previously mentioned. There, *Dataset_Metadata* class represents the usual metadata for a dataset, that is, metadata conforming to ISO or FGDC standard and containing typical sections such as the depicted as class attributes in the figure. Inheriting for this class, the *Aggregation_Metadata* class is an abstract class that includes the information necessary to document aggregations. And finally, this class is specialized into three different classes to describe the aforementioned types of aggregations: *multiple type collections* (*MultipleTypeCollection_Metadata* class), *single type collections* (class named *SingleTypeCollection_Metadata*), and *high-level aggregations* (class named *HighLevelAggregation_Metadata*).

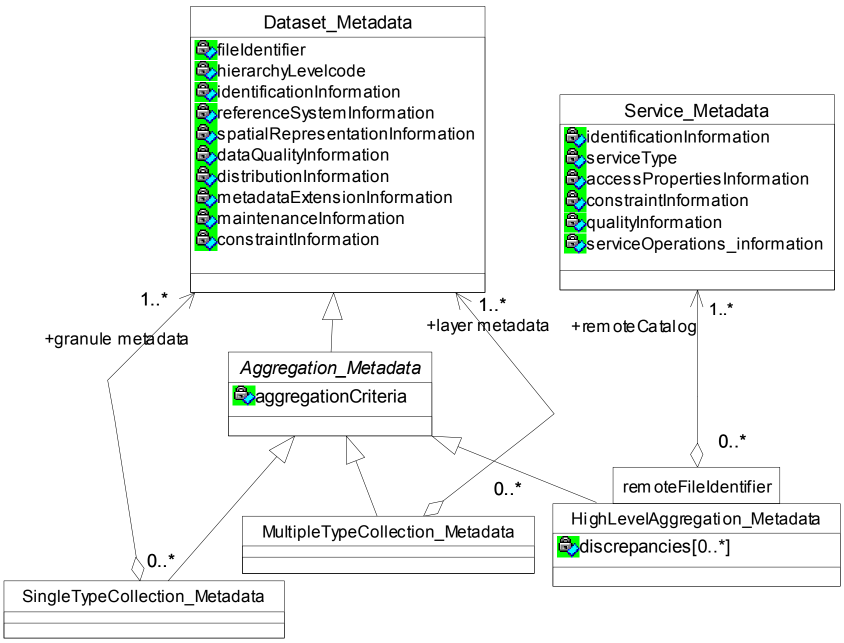

Fig. 2 Class diagram representing the different types of aggregations considered

Although it is not the objective of this section to describe *MultipleTypeCollection_Metadata* and *SingleTypeCollection_Metadata* classes in detail, it can be observed that they are connected to the *Dataset_Metadata* class. This is due to the fact that the metadata for a collection must maintain a pointer to the metadata that describes the components (granules, units, layers or any other type of component) of the aggregation. In a similar way, the metadata for a *high-level aggregation* must also provide the necessary information to access the individual metadata records stored in remote catalogs. Therefore, an instance of *HighLevelAggregation_Metadata* class must include the following information:

- First of all, it is necessary to know the identifier of each remote metadata record, which describes a component of the aggregation and which is stored in one of the different catalogs belonging to the infrastructure. And in addition to this, it is also needed the service metadata of these remote catalogs, that is to say, the necessary information to access the services offered by these catalogs, which really contain metadata for the aggregated components. Service metadata is represented in figure 2 by means of *Service_Metadata* class that should comply with emerging standards for description of GI Services like [13], which is used in OGC Web Services Stateless Catalog Profile draft specification [15]. And in order to maintain the pointer to each metadata record, an association between *HighLevelAggregation_Metadata* and *Service_Metadata* classes has been created foreseen. This association has a *remoteFileIdentifier* attribute, which allows the storage of each remote metadata record identifier.
- Besides, due to the heterogeneity of the components, it will be interesting to remark the elements which can not be unified, i.e. the not common information, which is depicted in the figure 2 as the *discrepancies* attribute of *HighLevelAggregation_Metadata* class. That would be the case, for example, of the information language or the spatial reference system used.
- Last feature of this type of *high-level aggregation* would be possibility to aggregate components whose metadata, apart from residing in distributed catalogs, conforms to different metadata standards. That feature has not been depicted in figure 2, but given the case, it would be necessary to specify the standard of each remote metadata entry.

Next section shows a real example where the use of *high-level aggregation* metadata results to be essential to provide an integrated and homogenized view of data merged from original resources produced at different regions and with different characteristics.

5. MAKING PROFIT OF HIGH-LEVEL AGGREGATION METADATA

In order to describe the potential of this *high-level aggregation* metadata, a complete use case is shown in this section, from the discovery of the *high-level aggregation* to the integrated view and analysis of geographic data.

Let us think about the case of digital ortho-photography that is produced in each node (or region) of the infrastructure. At each node, digital ortho-photography is managed as a *single type collection* but holding their own characteristics not necessary homogenous to the rest nodes of the infrastructure. For example, depending on the country directives ortho-photography is produced at different scales, geo-referenced using different spatial reference systems or uses a different tiling division system to manage data more efficiently.

The first step to create an integrated view of digital ortho-photography should be the creation of a *high-level aggregation* metadata entry for the central catalog, which would maintain references to the metadata entries describing the digital ortho-photography at each node. This way, the catalog search services of the infrastructure would allow the user to discover a unique collection of ortho-photography for the Pyrenean regions.

However, from the user perspective, it is needed something more than the discovery of a collection which groups data coming from different sources, which are probably not compatible. A usual requirement should be the obtainment of ortho-photographs over the borderline between Spain and France countries, where original data comes from two different organisations and must be merged on demand.

Since the objective of the infrastructure is to provide a tool that facilitates decision-making, the infrastructure should offer geo-processing services able to obtain on demand a uniform view of data. The main objective of these geo-processing services should be the avoidance of discrepancies due to the heterogeneity from data sources. Some typical tasks for these geo-processing services could be:

- Unify spatial reference systems: While French regions could be using a geographic coordinate system, Spanish regions could use a grid coordinate system like UTM, or although using same spatial reference system, they could belong to different zones (e.g. UTM zone 30 and 31).
- Unify scales: ortho-photographs could have been taken at different scales.
- Unify tiling division systems: In order to manage large amounts of data, it is usual the use of a tiling division system. Basic geospatial data at scale 1:25.000 in Spain, for example, shares the same tiling structure with its own tile identification system and there is no overlap between tiles. However, this tile division has only national character and is not probably compatible with neighbour-nations in many cases.

In order to develop these geo-processing services, standardized and fully detailed metadata becomes essential. The only way to automate these geo-processing services is to rely on accurate metadata detailing crucial aspects for geo-processing as spatial reference system information, scale, spatial data representation and distribution information for online data access. Therefore, these geo-processing services should per-form two fundamental tasks. The first task should be the analysis of the metadata entries provided from each node of the infrastructure. Metadata entries should con-form to same (or equivalent) standards such as CSDGM or ISO 19115 comprehensive profile which includes metadata elements for geospatial data exploitation. Then, discrepancies must be gathered in order to obtain the list of geographic operations, which must be applied to the distributed data. In a second step, geographic data should be downloaded and operated so as to produce the required unified data for the area of interest.

6. CONCLUSIONS

This paper has presented an approximation for the development of natural risk management tools based on the integration of resources from each one of the communities that participate in the intercommunity area. This approximation would avoid a clear waste of money because allows the reuse of these resources and permits the incorporation of information created by the risk management area to the normal operation of the rest of entities.

Due to the heterogeneity and distribution of the nodes of the SDI, it has been necessary to define a new concept of aggregations within metadata, *high-level aggregation*, which provide a joint view of the data produced, managed and documented at different nodes of the infrastructure. Moreover, this *high-level aggregation* metadata enables the creation of geo-processing services that can produce, on demand, unified data by merging two resources semantically equivalent but with technical discrepancies.

The work presented is included in a collaborative research project initiated by investigators at three Spanish universities to build technological components for the development of Geographic Information Infrastructures. The state of the project is still at first steps and involves new and immature technologies, above all those regarding GI interoperability. The evolution of the project and technologies themselves will imply a refinement in design and architecture.

7. ACKNOWLEDGMENTS

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