# Geographical information systems interoperability through distributed territorial data exchange

(Extended Abstract)

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**Abstract**

A key preliminary requirement for data interoperability in the field of geographical information systems is to understand which data are available and to which degree they can be used for the specific aim one is targeting.

In this paper we describe, focusing mainly on interaction and publication services, the design and development of the prototype of a system addressing the need of sharing and reusing geographical data and whose development was promoted by AIPA, the italian Authority for Informatics in Public Administration.

Highlights of the system are its support for end-users browsing through metadata describing territorial information, both at a geometric and at a textual level, and the presence of automatic mechanisms to signal and dispatch to end-users updates to territorial data known to the system.

**Keywords**: geographical information systems, data interoperability, information systems integration, federated databases, inter-organization cooperation.

## 1 Introduction

Managing any given portion of territory is usually a complex task for any Public Administration. This is partly due to the intrinsic complexity of geographical information and partly to the need of sharing and reusing databases and information flows.

It has been a usual practice in the past, at least in Italy, to autonomously develop, from every (public and private) organization interested to some aspect of land management, its own information systems. Since every such an effort was targeted at its immediate requirements, the possibility of reusing and/or sharing geographical data was almost impossible. This resulted in a great waste of resources, above at all when confronted with the large increase in power and

sophistication of computational resources available in recent years. Also, it was apparent that a major obstacle to reuse was the lacking of a common "geographical reference layer" to which homogeneously correlate all kinds of geographical information.

Hence, by initiative of the italian Authority for Informatics in the Public Administration (AIPA), a research and development project (SCT – "Sistema di Comunicazione di Dati Territoriali") was started to investigate mechanisms to allow lowering of costs related to geographical information systems development and maintenance and to enable a true reuse of geographical data by many users and many organizations.

The design and prototyping of SCT was carried out by a consortium led by Telecom Italia and comprising three more large companies (namely, ESRI, Finsiel and IBM). Such a project is one of the steps taken by AIPA in the joint cooperation framework[1] with the Region Association and the Municipality Association for coordinating efforts related to geographical information systems.

The main objective of SCT is to certify the existence of territorial data, to publish and to distribute them in public organizations. In this way geographical database production process is streamlined and improved in two ways:

- territorial data already available at public administrations can be reused, due to the fact that coherent documentation is available and support for a reuse/develop cost-benefit analysis is available,
- a 'mediating place' among local and central administrations for the cooperative development of new geographical databases, when existing ones are not reusable, is set up.

Given that the acquisition cost for territorial data is much higher than the management and processing costs, saving money from the acquisition process make more resources available for end-users application development.

SCT certifies existence, completeness and coherence of geographical data and their related documentation, while each involved administration, certifies reliability of data they provide. Their certification is related to the administrative processes for which data have been acquired (e.g., taxation on real estates). Reliability means, in this context, data quality, legal value of data, and validation of the data production process.

At high level, SCT may be described as a set of distributed processes connecting a set of providers and end-users of territorial data and providing publication and access services to territorial data known to the system itself. By means of these processes then SCT allows to certify:

- the existence of territorial data at provider sites,
- the use, at end-users sites, of territorial data retrieved by means of the system itself.

SCT's services allow administrations to get information they need to decide, on the basis of their own criteria, technical and economical feasibility of the use of territorial data available through SCT within administrative processes internal to the administration itself.

In such a way SCT supports cooperation among administrations to build territorial information bases focused on specific sectors (e.g., transportation) with considerable saving of resources.

Key architectural aspects of SCT are:

[1] Namely, "Intesa Stato-Regioni-Enti Locali per la Realizzazione dei Sistemi Informatici Geografici di interesse generale".

- the description of geographical data through metadata,
- mechanisms for data geo-referencing and certification,
- the definition of providers and end-users of geographical data,
- the definition and supply of data and service flows between providers and end-users.

Interoperability has been a subject of database research since a long time, with a variable level of attention. In the last years, given the unavoidable issue of legacy systems and the explosion of network connectivity, its relevance has again increased (e.g., see the recent special issue [15]). Products allowing to deal with data access to heterogeneous information sources are being provided by all the major DBMS vendors [15] and novel approaches are being prototyped by universities (e.g., [13]). The whole area of information systems integration is a highly researched topic [9], with the goal of allowing users to make an effective use of the wealth of data easily reachable through communication networks.

A recent series of workshops on engineering federated database systems and information systems [6, 7, 8] has pointed out that one of the open research issues in this area is the integration of legacy databases in a federation of autonomous heterogeneous information systems and the ability of maintaining coherence of information representation during evolution over time of the systems involved in the federation.

One widely followed approach to meet the above discussed goal is based on the design of a suitable Data Warehouse [10, 14, 16] and it is widely known that data integration is at the heart of data warehousing [11, 12].

We have addressed the data interoperability issue within a general approach focused on direct inter-organization cooperation and have developed an new architectural approach aiming at this target [1]. An example of a large-scale system designed according to this approach is discussed in [2].

The paper is structured as it follows. In Section 2 we review how territorial data are described in SCT. Section 3 describes publication services of the system, while Section 4 sketches samples of end-user interaction. SCT's exchange services are described in Section 5. Section 6 concludes the paper. More details on system architecture and metadata organization can be found in [3].

## 2 The description and geo-referencing of territorial data

Definition of geo-referencing of territorial data in SCT has been based on the normalization documents developed by the working group CEN TC 287 and on the national rules defined for the implementation of the italian National Geo-referencing Network ("Rete di Appoggio plano-altimetrica Nazionale"). Also, common technical specifications under development by the italian National Technical Committee for the Coordination of Geographical Information Systems have been taken into account.

Registered users wishing to make their territorial data available for distribution through SCT have to give information needed to describe their data in the metadata base. This Geographical Information Description (DIG = "Descrizione Informazione Geografica") is a set of metadata which have to be provided for each homogeneous set of territorial data. Examples of homogeneous set of territorial data are: ortho-photographies of land coverage of the Ministry of Agriculture, meteorological charts of the Military Aviation Service, utilities network maps of a Region. If such a set has multiple thematic layers, that can be separately supplied (e.g., different

layers for different utilities in a network utilities map), then its DIG has to be further specified to describe the various layers.

DIGs with different semantic characteristics but describing the same portion of land according to a same geometric partition are then grouped in *clusters*. Spatial and geometric characteristics are thus specified only once for all DIGs in the same cluster. Finally, clusters are hierarchically structured according to thematic classes, predefined in SCT. Each DIG hence describes a semantically homogeneous set of geographical data, that can be supplied as a whole or in parts (datasets). A *dataset* is therefore the atomic unit of supply by SCT to end-users. For example, in a DIG describing meteorological data recorded in various base stations on the earth, a dataset may refer to all data recorded at a specific station. For each DIG the provider has also to give a set of vectorial data, giving (according to specifications below described) geo-referencing and extension of provided dataset(s); for DIG describing point data geo-referencing is provided by means of correlation to points of the National Geo-referencing Network (see below).

New DIGs are inserted in metadata base by providing information required for a correct execution of search mechanisms available in the publication subsystems of SCT. Required information is that on data quality, cost of supply, meaning (i.e., portion of reality represented), and contract/price scheme for supply. It is also required to classify data with respect to a set of classes for geographical data description specified by SCT's Managing Agency. Optional information regards schemes describing how data are used in specific geographical information systems.

Certification of provided data its guaranteed by obtaining from the provider declarations about data quality and, whenever it is possible, correlation between provided datasets and the National Geo-referencing Network. This latter constitutes the standard geo-reference for all datasets in SCT.

Points of the National Geo-referencing Network are managed within SCT as other territorial data: they are datasets that can be provided to end-users. SCT metadata base contains therefore DIGs for the National Geo-referencing Network and DIGs for local geo-referencing sub-networks that are coherent with the national one, whenever they exist. To allow end-users to browse and examine data in SCT while understanding what to select, points of the National Geo-referencing Network are freely available, for visualization and cross referencing with dataset to be downloaded, at a coarse resolution level. Should the end-user need also a supply of these points, this is managed as a normal exchange flow between provider and end-user, subject to standard supply conditions for that dataset.

Each DIG in the metadata base has a geo-referencing feature associated, i.e. a dataset providing localization on the territory for each provided dataset relative to the DIG. Such a geo-referencing feature can be defined in different ways. A main one is to choose one of the pre-defined geo-referencing features. These are those describing administrative boundaries (at national, regional, provincial or municipality level) and those describing boundaries of the official land maps from the National Survey Office (at 1:200.000, 1:100.000, and so on, scale). If none of the pre-defined features is able to correctly localize datasets relative to that DIG, than the potential provider sends to the SCT Managing Agency a vectorial map, in absolute geographical coordinates, of the extension of dataset(s). The Agency then establishes the geo-referencing association between this vectorial map and the DIG and inserts information into the metadata base.

Analogously, for each provided dataset, the provider can specify a correlation between the dataset itself and at least three points of the National Geo-referencing Network. On the basis of these correlations SCT's Managing Agency then establishes, using suitable geometrical operations, a complete correlation between dataset boundaries and points of the National Geo-

referencing Network.

The subsystem of SCT dealing with metadata, beyond providing the above described functions to end-users for loading new DIGs, also manages service data, like the points of the National Geo-referencing Network. Management and updating operations on the metadata base are directly under the responsibility of SCT's Managing Agency.

# 3 Territorial data publication subsystem

The subsystem for territorial data publication executes all processes needed to register SCT's users and to publish available DIGs. This subsystem also manages query functions, accessed through Internet and/or Intranet.

SCT publication services allow:

- to perform structured queries according to classification hierarchies defined in the metadata base: the results are datasets whose DIGs satisfy query parameters. These datasets can be visualized and related information present in SCT can be examined to decide whether there is good match with end-user requirements;
- to query in a free format by providing, like it happens for search engine Internet sites, keywords describing end-users needs. As before, datasets whose DIGs contains the given keywords are return for end-user's further scrutiny.

Providers and end-users of geographical data need to register as users of SCT and provide their identification information to be able to fully use all SCT services. A reduced set of visualization services is guaranteed to anyone accessing SCT through Internet.

Providers have to provide all information needed for a DIG insertion into metadata base and those required to activate data flows among a provider and end-users.

Requests for registration are examined off-line by the SCT Managing Agency which, upon approval of the request, send access keys to the user. In such a way a higher reliability level is obtained for what regards data and patterns of their use.

An interesting set of functions are those related to the management of *use schemes*. A use scheme describes a pattern of use of a territorial dataset in terms of data type, geographical extension, constraints on quality, cost. End-users can retrieve data from SCT also on the base of use schemes they specify, so to be sure not only that retrieved data describe reality they are interested to, but also that such data are used exactly in the same kind of administrative processes they are responsible for. Moreover, end-users can insert their customized use schemes for geographical data, and this allows to SCT to collect statistics about usage of (actually present or yet to be acquired in the system) data.

Data published by SCT are all those inserted by a user:

- personal data of users;
- use schemes for data (e.g., intended use, validity conditions, ...);
- supply conditions for data (e.g., costs, constraints on use, standard contract, ...);
- DIGs;
- geographical reference data for datasets: these are usually vectorial maps, needed for the user to exactly understand which part of the land a dataset refers to, defining:

  - geographical extension of available datasets (e.g., the municipality boundary for the roadmap of a public transportation service);
  - joint map for those datasets that can be supplied also one at a time (e.g., a map showing the union of various cadastral maps, in the case a cadastral map can be supplied alone as a dataset);
  - geographical extensions specified by use schemes (e.g., a municipality boundary in a use scheme relative to waste collection local taxation process)
- optionally, examples of datasets (usually in form of images).

Service data supporting publication services are:

- points of the National Geo-referencing Network, needed for purposes of localization during browsing; these are expressed at a reduced resolution level in the Gauss-Boaga coordinate reference system, projected on a single reference zone for national data;
- various hierarchies used for classification of DIGs according to the different semantics characterizing territorial data;
- pre-defined use schemes: these are made up by a set of data types and a set of constraints on data quality, cost, and geographical extension; use schemes are used during search process to retrieve data needed to end-users;
- users defined use scheme: these are added during SCT operation both by providers, for those use schemes peculiar of data they provides, and by end-users, for those use schemes referring to data not yet available in the system.

# 4 Interaction with SCT

As already introduced the basic retrieval query is through use schemes. Pre-defined use schemes, prepared either by SCT's Managing Agency or by data providers, are available in SCT. End-users registered as such can also insert and modify their own use schemes and adopt these for the retrieval process. If desired data are not currently available through SCT, the relevant use scheme is used as a mechanism to activate a request for future supply.

To restrict a query to a given portion of land, end-users can use anyone of the territorial service data available:

- points of the italian National Geo-referencing Networks,
- administrative boundaries at different hierarchical levels from Regions to Municipalities,
- boundaries of italian Official National Land Map partitions.

Selection of the zone of interest can happen either directly by drawing with a mouse on the screen or by inserting name(s) of administrative entities or of official map partition sheet. During this process it is always possible to switch back and forth between the point-and-click interaction mode and the name-insertion mode. When browsing happens through selection of points of the National Geo-referencing Networks the area selected for the query is the convex hull of the selected points. Dataset selection then happens by choosing all datasets whose area intersect such a convex hull and all datasets that have been geographically correlated, when inserted into SCT, to the selected points.

An example of interaction with SCT is presented in figure 1, where it is shown a user selecting a DIG on the basis of its geographical location. In figure 2 a subsequent selection step, at finer

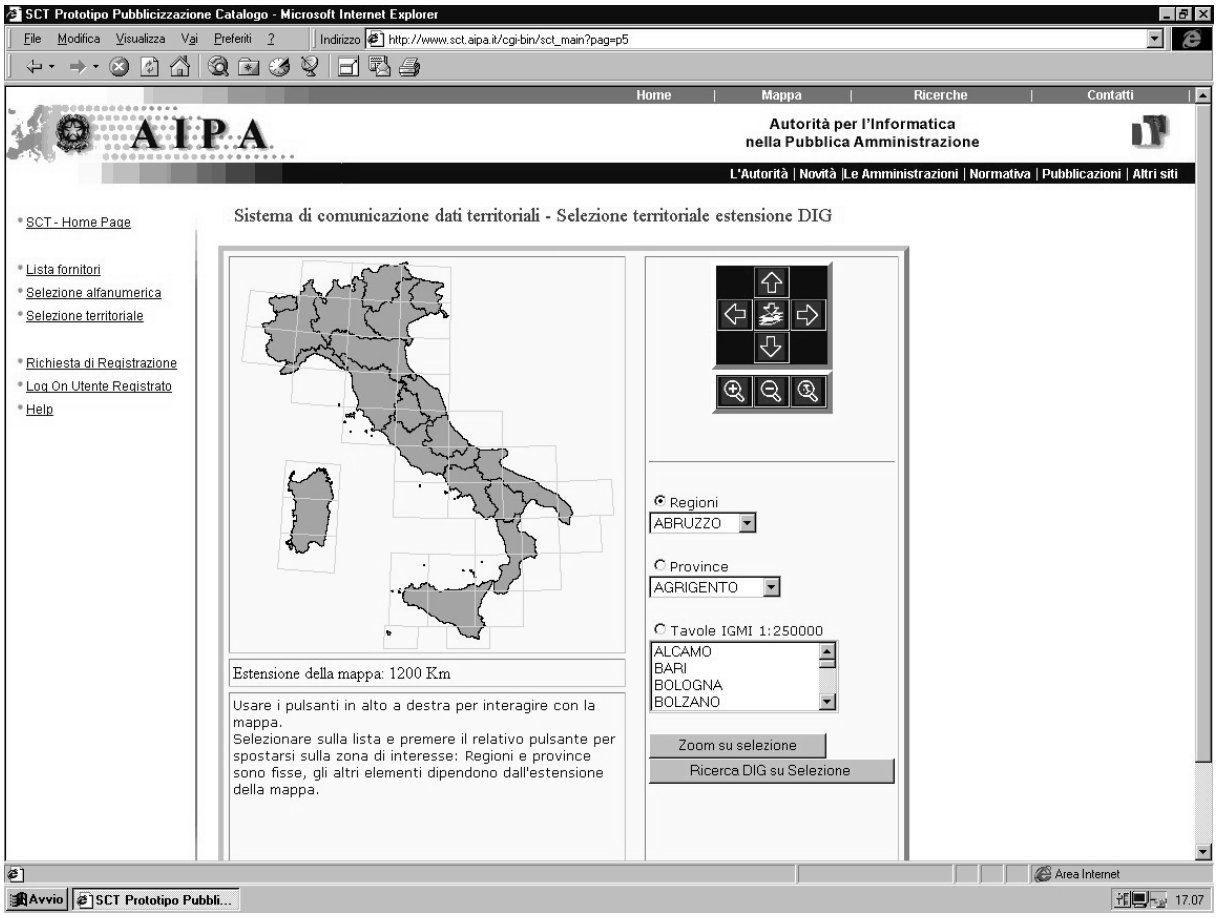


Figure 1: An example of DIG selection

resolution level, is shown. At the end of the selection process (see figure 3) the DIG of black & white digital ortho-photo at average scale 1:40000 from the 1994 photo campaign is retrieved.

Once an end-user, by querying and browsing and visualizing in SCT, has acquired sufficient confidence in the utility of retrieved data for its purposes, SCT exchange services can be activated to enable transferral of data from the provider to the end-user. It is crystal clear the importance of this kind of extensive and accurate browsing functions to enable and support a true exchange and reuse of territorial data.

SCT is, in fact, more than just a catalog of territorial data. It allows the exchange of geographical information and foster the building of shared base of knowledge relative to the use of geographical data. Such a knowledge is based on schemes (or patterns) of use of data declared by end-users as well as by providers. Potential end-users may browse through this knowledge base and find data most useful to their purposes. At the same time they can discover how to use data within administrative processes they are responsible for. Also, this knowledge base is the starting point for planning and defining new geographical databases.

Through the cooperation and the data exchange supported by SCT it is thus possible to reduce redundancy in territorial databases and increase synergy among different uses of the same data item in different administrative processes, all referring to the same part of land.

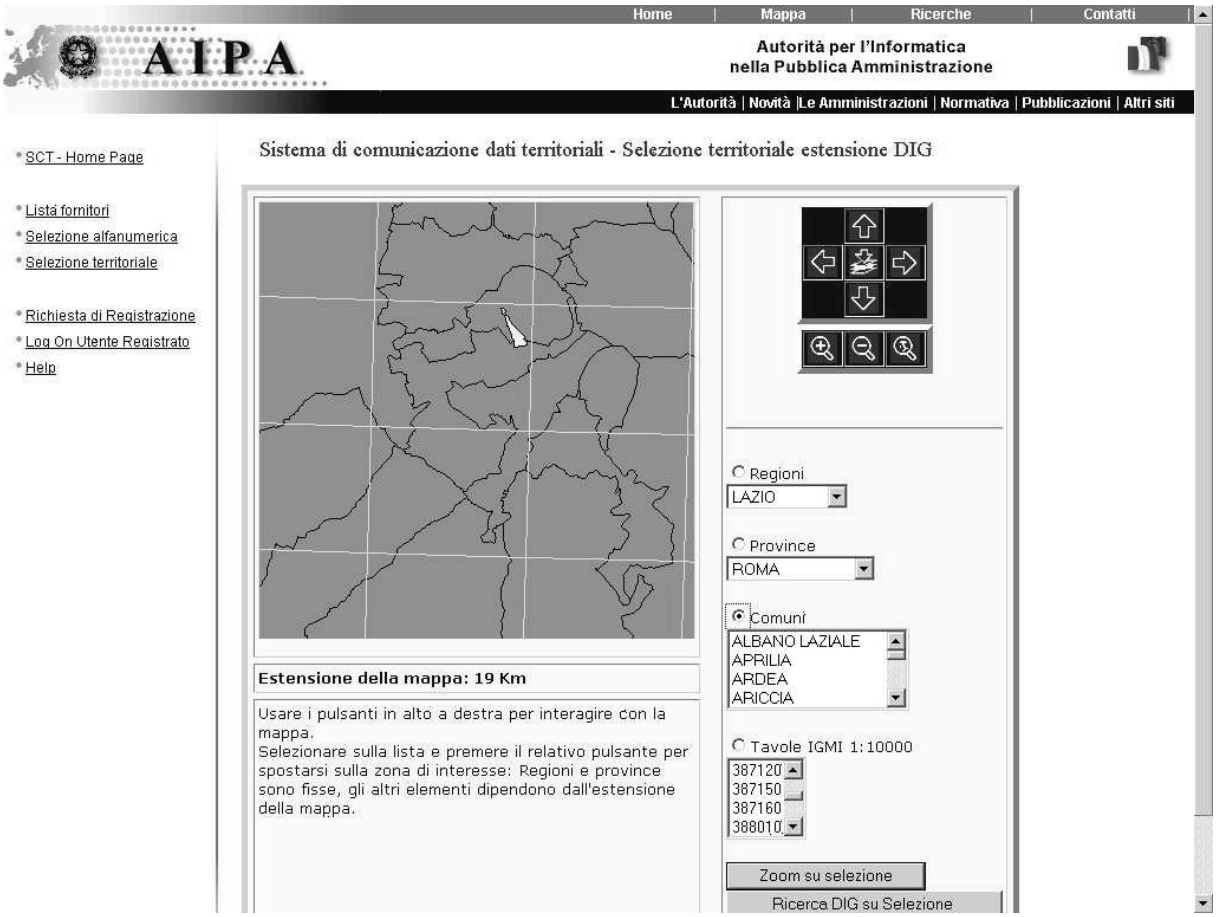


Figure 2: A finer selection step

# 5 Territorial data exchange subsystem

The usual sequence of steps activating a data exchange is the following: first the end-user, interacting with publication subsystem retrieves territorial data of interest; then, interacting with the exchange subsystem, activates the supply request; finally, a supply contract is signed (electronically, if the corresponding infrastructure has been set up), payment is activated (through electronic means, if set-up), and data are sent.

The exchange subsystem then provides all services needed to run and manage data exchange flows, including security and accounting functions. In the following, various services are discussed in more detail.

## 5.1 Transportation and interoperability services

This kind of services are the usual ones available on a data communication network: the only peculiarity is the large quantity of data that may be exchanged. This of course requires a bandwidth large enough to reliably and efficiently execute the exchange process.

One more peculiarity regards the relation between SCT and the Unified Network of the italian Public Administration (RUPA) [5]. SCT is mainly devoted to public administration needs, hence it is accessed through RUPA, but since it may be used also by private organizations (and this is actually important to increase its utility), it is also possible to access it through Internet or

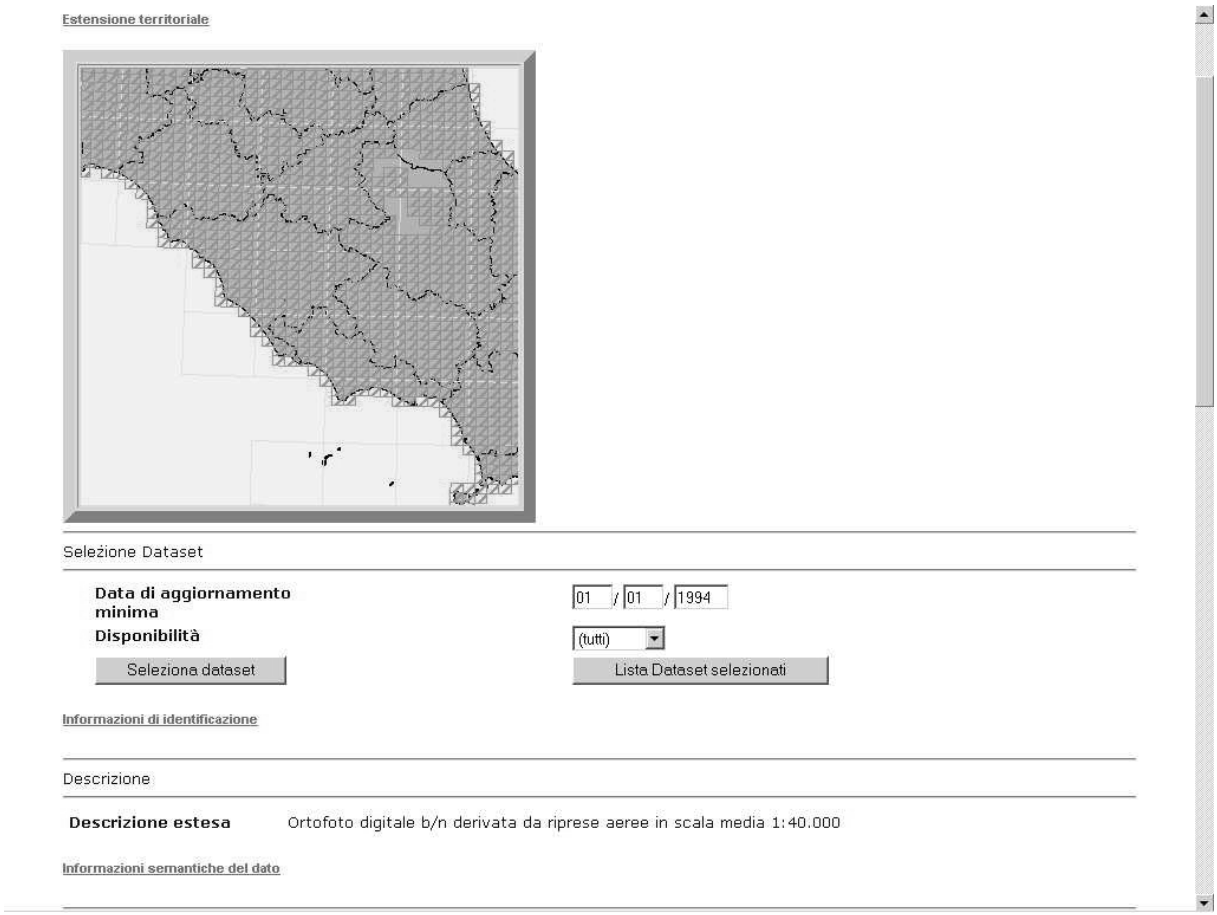


Figure 3: A DIG retrieved at the end of the selection process

other networks connected to Internet.

### 5.2 Base services

These are functions ensuring security in access and transportation of data: examples are techniques for authentication and authorization, non-repudiation of transactions, confidentiality of data exchanges, certification of data integrity, and so on. Which ones of these services are needed, and to which degree, it is mainly a matter regarding the organizational model that SCT operations will have in the final deployment phase.

### 5.3 Services for data exchange

A data supply flow is fully self-identifiable, as it is the case for all service flows within SCT: this means the flow itself contains all information needed to completely identify destination of data, dataset(s) exchanged, requested service(s), data provider, and possible technical constraints on data supply. This self-identification feature, naturally ensured by the asynchronous approach adopted as basic communication protocol in SCT, is absolutely needed to ensure a true decoupling between end-users, system, and providers, hence a more efficient management of all services.

A data supply flow can be correctly executed, certified, and accounted only through a three-part

relation: end-user, system, and provider. After an end-user has requested a dataset and such a request has been sent to the provider, this prepares the flow according to a standard format and encapsulates dataset by means of an header allowing a correct management and routing of the flow. After a flow has been received by an end-user, this checks integrity and correctness of data contained in it. When SCT receives from the end-user the notification of the correct arrival of the requested dataset, the system is able to certify the supply service.

Data exchanged in a supply flow does not need to be in a standard file format. Instead, each provider may use the format best suited to its information system and to the tools used within it. It is only the protocol used for the exchange that has to comply with a standard defined in SCT and based on XML. Such a standard envisions mechanisms for the description of metadata and for encapsulating dataset in an header containing a standard set of information items. For more details on this aspect of SCT see [3].

Also data needed for certification and accounting of exchange flows are encapsulated by means of a standard header, predefined in SCT, containing all elements needed for these purposes.

Further services of this subsystem allow to compress data, to clip portion of data according to a given geographical boundary, to extract single data layers in a dataset, and to manage update processes for datasets.

### 5.4 Services relative to the organizational model

The exact organization of this kind of services will strictly depend on the way SCT will be managed in the full operation phase. They are relative to:

- documentation of service information flows,
- extraction of accounting information from service information flows,
- management of accounting services, taking into considerations both quantitative and qualitative aspects,
- possible management of e-commerce functions related to data exchange needs, and
- cost-benefit analysis of usability of a geographical dataset.

Concerning the control of services supplied by SCT, a suitable set of measure parameters has been identified and consequently processing functions have been implemented to allow to analyze quality and consistency of:

- services directly supplied by SCT,
- data and services supplied by providers,
- exchange flows requested and executed (both periodic and spot ones),
- accesses to publication services,
- data requested to SCT but not yet available, and
- declared use, by end-users, of data obtained from exchange flows.

### 5.5 Automatic distribution of updates

A critical issue for ensuring a true success of data exchange services is the availability of mechanism to signal and distribute updates to each interested user, so that each one receives all and only the really relevant ones, whenever they are available.

SCT has tackled this problem by letting the user itself decide and define exactly which updates are desired. A user accomplishes this by inserting a use scheme, which describes which kind of geographical data are of interest for the user, and which are the constraints on data quality, cost, and geographical extension, and by activating for such a use scheme the *signaling* option. Parameters that can be specified for update receival are exactly the same, both textual and geometric ones, used in the interaction with the publication subsystem to select and retrieve relevant geographical data. In such a way, among all updates in the system, all and only those satisfying the activated use scheme(s) will be sent to the user.

The mechanism chosen in the prototype to send updates is simply the delivery of e-mail messages. This is at the same time very simple to implement and use and widely available to everybody. In the full operation phase further and more complex mechanisms can be implemented, if needed for particular kind of users. Also, with more sophisticated distribution mechanisms it will be possible to implement also a policy for the automatic distribution of updated datasets, and not only of updated metadata.

# 6 Conclusions

We have presented and discussed in this paper SCT ("Sistema di Comunicazione di dati Territoriali") a prototype designed and implemented in Italy in an effort, coordinated by the italian Authority for Informatics in Public Administration (AIPA), to increase sharing and reuse of territorial data.

SCT is an innovation with respect to the current state of the art of available systems supporting data interoperability in geographical information systems due to the unified model it features for:

- data publishing,
- selection of relevant data for end-users,
- cost-benefit analysis,
- data supply from providers to end-users.

In such a way SCT overcomes and solves current problems currently limiting a widely adoption of data distribution mechanism for geographical information systems in the public sector, namely:

- lack of primitive functions for selecting data really relevant to end-users,
- low support for evaluating data quality,
- hard to evaluate cost-benefit analysis for reuse,
- scarce control on telematic data supply.

Due to these problems it has many times happened in the past that data supply agreements of episodic nature have distortedly become reference for the market.

Furthermore, SCT is a natural mediating place between territorial data providers and users and in this way it sets up a framework for defining and enforcing a public policy in the sector. This characteristic is not limited to the territorial data field, since the adopted techno-organizational approach is of general nature and its services can be used to deal with publishing, management and exchange of data in other relevant sectors for Public Administration [4].

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