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TOWARDS THE GEOGRAPHIC METADATA STANDARD INTEROPERABILITY

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1. INTRODUCTION

The geographic information (also known as geo-spatial data) is the information that describes phenomena associated directly or indirectly with a location with respect to the Earth surface. This information is vital for decision-making and resource management in diverse areas (natural resources, facilities, cadastres, economy...), and at different levels (local, regional, national or even global) [1]. Nowadays, large amounts of geographic data are gathered by different institutions and companies. In fact, it is recognized that around 80% of the databases used by the public administration contain some kind of geographic reference (postal codes, cartographic coordinates...). Nevertheless, in many cases geo-spatial data-consuming companies or people do not find the data they need and they usually pay data suppliers for custom-made products. Moreover, it is usual to find that, even among different divisions of the same company, there is no knowledge about what data is currently available. This lack of synchronism leads into a consecutive recreation of data with similar characteristics.

This ignorance about "what already exists" is not new in other scientific areas like biblioteconomy (specially in the case of the digital-libraries) and to solve it requires the use and creation of metadata. The metadata ("data about the data") are the mechanism to characterize data and applications, which enable other applications to make use of these data or invoke their services. The metadata records, each one describing a specific resource, are grouped in catalogs that provide users with the possibility of identifying the resources of their interest. Therefore, the geo-spatial data catalogs (containing metadata with geo-spatial profiles) constitute the necessary tool to put in touch consumers with information suppliers.

The geographic metadata describes the content, quality, condition and other characteristics of the data that allow a person to locate data and to understand them. As it is mentioned in [2], the creation of metadata has three main objectives:

- The first one is to organize and maintain the investment in data made by an organization. As personnel change or time passes, later workers may have little understanding of the content and uses for the digital data previously created and may find that they cannot trust results generated from these data. That is the reason why complete metadata descriptions of the content and accuracy of a geospatial data set will encourage appropriate reuse of the data. Moreover, such descriptions may also provide some protection for the producing organization if conflicts arise over the misuse of data.
- The second objective is to provide information to data catalogs and clearinghouses. Applications of geographic information systems often require many themes of data. However, few organizations can afford to create all data they need on their own. Often data created by an organization also may be useful to others

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and 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. In fact, metadata should accompany the transfer of a data set. In this way, metadata aids the organization receiving the data process and interpret data, incorporate data into its holdings, and update internal catalogs describing its data holdings.

In order to extend the use and understanding of metadata through different communities of users, e.g. to enable distributed searches across a network catalog servers, it is necessary to use well-defined contents and thus adjust them to a metadata standard. In this way, there have been a lot of standard proposals to describe consistently a geographic resource, which have arisen at national or global level and with different scopes. Some of the most extended ones are:

- The “Content Standard for Digital Geospatial Metadata” (CSDGM) of the Federal Geographic Data Committee (FGDC) [2, 3]. This American initiative is the only one that has the rank of standard at this moment. It was carried out in the United States by the FGDC and approved in 1994. It is a national standard for spatial metadata development for give support to the construction of the United States Spatial Data National Infrastructure. This standard has been adopted in other countries like South Africa or Canada.
- The “Recommendations about metadata” issued by the Center for Earth Observation of the European Commission [5].
- The European voluntary norm prENV 12657 [6].
- Dublin Core [7]. It is a metadata standard of general outreach, very popular in the world of digital-libraries, which is being adopted by geographic information world in order to enable compatibility with other cataloguing information systems.
- The draft version of international standard DIS 19115 [8]. In 1992, the International Standard Organization (ISO) created the committee 211 (ISO/TC 211) with responsibilities in “geomatics”. This committee is now preparing a family of standards that, in the near future, will obtain the rank as official international standard. One of these standards is the Nr. 19115, in charge of the standardization of geo-spatial metadata.
- Other national and regional initiatives. For instance, the Spanish norm for geographic information exchange, known as MIGRA ("Relational Exchange Mechanism for Geographic Information constituted by aggregation"), incorporates a metadata section within the data to be transferred. This norm was proposed by Normalization Technical Committee 148 of AENOR, the Spanish National Standardization Agency, and according to the objectives of the norm, it should be valid until the arrival of a stable CEN European norm or an ISO international standard. At present, there is an initiative to study the compatibility between MIGRA and ISO standards.

Apart from the chosen standard, the metadata cataloguing systems must support (recognize) three forms of metadata [1]: the implementation form (within a database or storage 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 last two forms, there is a general consensus about the use of XML (eXtensible Markup Language [9]). First of all, it includes a capable markup language with structural rules enforced through a control file (Document Type Definition 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 [10]), an XML document may be used along with a style sheet to produce flexible presentations or reports of content according to user requirements.

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The intention of the different organizations who have proposed these standards, many of them still drafts or pre-standards, is the harmonization of all the initiatives around ISO as soon as it is approved as international standard. Nevertheless, at this moment, the FGDC standard is the most widely used in GIS world and there exists multiple tools for the creation of metadata. Therefore, until the moment of having a unique world-wide recognized standard, and to reach a wider range of user communities, the metadata cataloguing systems should offer those metadata in accordance with several of the most popular or generalized metadata standards. As the number, size and complexity of the metadata standards grow, the task of facilitating metadata in different standards becomes more difficult and tedious. In order to minimize the cost of time for the creation and maintenance of metadata and to maximize its usefulness to the wider audience of users, it should be desirable to use a unique metadata standard in creation labours and provide automated views of metadata in other related standards. According to this philosophy, the tendency of the current cataloguing systems is to interchange metadata in XML which conforms to a specific standard on user demand, that is to say, providing different views of the same metadata in ISO, FGDC, or more generic standards like Dublin Core. In order to maintain this interoperability across related metadata standards, it is necessary the creation of software systems able “to speak several metadata dialects”, that is to say, systems that provide crosswalks (or bridges) between metadata standards and which make profit of emergent technologies like the XML and the XSL, and as it will be seen in next sections.

Nevertheless, the construction of crosswalks between standards is much more than the use of a series of programming technologies. A crosswalk specifies the mapping between two related standards, thus enabling communities that use one standard to access the content of elements defined in another one. Unfortunately, the construction of crosswalks constitutes a difficult and error-prone task that requires deep knowledge and vast experience with the standards. The obtainment of the knowledge required to construct a crosswalk is particularly problematic since each metadata standard has been developed frequently in a independent form and therefore different terminology, specialized methods and processes are used. Moreover, the maintenance of crosswalks between metadata standards which are not stable and subject to changes is even more problematic due to the additional requirement of adjusting crosswalks to historical versions. For that reason, the harmonization in the consistent specification of related metadata standards is vital to the development of crosswalks. This harmonization enables the creation and maintenance of metadata conforming to a unique standard, but having the capacity to match the metadata elements of this selected standard with elements of related standards. Besides, this common terminology and methodology simplifies the use, development and implementation of these standards. The objective of this work is to present the process followed to carry out a series of crosswalks that enable interoperation across some of the most relevant standards for geographic information metadata.

The rest of the article is structured as follows. Next section proposes a general process to formalize metadata standards and construct crosswalks. Section 3 presents the crosswalks developed and explains, as an example, the application of the process for the construction of one of them. Finally, this work ends with a section of conclusions and future work.

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2. CONSTRUCTION OF CROSSWALKS BETWEEN METADATA STANDARDS

This section presents the steps of the process that has been followed to construct a series of crosswalks between standards (these crosswalks will be introduced in next section) and that simplifies its implementation by means of the use of formal specifications and automated mechanisms. The process has the following steps:

- Harmonization: This phase aims at obtaining a formal and homogeneous specification of both standards.
- Semantic mapping: In order to determine the semantic correspondence of elements between the standards of metadata a deep knowledge of the origin and destiny metadata standards is required. As result of this phase, a mapping table is created.
- Additional rules for metadata conversion. Apart from the mapping table, it should be necessary to provide additional metadata conversion rules in order to solve problems such as different level of hierarchy, data type conversions, etc…
- Mapping implementation: The last objective of the process is to obtain a completely automated crosswalk by means of the application of some type of tool. In this way, maintaining only one set of metadata, searches and views can be provided according to the different families from metadata.

The following subsections present further details of each one of these steps.

2.1 Harmonization

Many of the metadata standards use similar properties in the definition of their content elements. Some examples of similar properties could be: a unique identifier for each metadata element (for example: tag, label, identifier); a semantic definition for each element; the mandatory, optional or conditional character of each element; the multiplicity or allowed number of occurrences of an element; the hierarchical organization with respect to the rest of elements; or constraints on the value of an element (e.g. free text, numerical range, dates or a predefined code list). Once these properties are fixed, each metadata standard can be described in a similar way. Consequently, similar processes can be applied to related metadata standards, thus simplifying not only standards implementation but also the development of new crosswalks among them.

The generalization and formalization in the specification of metadata standard properties are possible by means of a canonical representation or a specification language. This procedure is analogous to the specification of a programming language syntax using the well-known notation Backus-Naur-Form (BNF [11]). In fact, thanks to the circumstance that most standards use XML as exchange and presentation format, they also provide a DTD that formally their syntax.

Nevertheless, a mere syntactic description of a metadata standard is not enough to store all the information necessary to automate the development of crosswalks. For instance, a minimum set of data types must be defined as a basis to obtain from it the derived data types that are required to represent all the elements in the target standard. And in addition to this, as it happens with BNF, a metadata specification does not contain information about the semantics of elements. For that reason, in this step it is proposed the creation of a table (that could be implemented by means of the use of a Excel sheet) describing the elements of each standard apart from the DTD available for each standard. In this table, each element of metadata will be defined by means of the following fields:

- Nr: Number assigned in its own metadata standard according to its level in the hierarchy.
- Longname: “long” name assigned by the standard to this element. Besides, it is recommended to indent sections and subsections of metadata in order to show the hierarchical structure of the standard.

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- Shortname: "short" name of the element. This shortname usually corresponds with the tag used for XML encoding of metadata.
- Car: multiplicity and mandatory constraints that the standard impose on this element.
- Description: semantic definition of the element.
- Datatype: datatype for the values of this element.

2.2 Semantic mapping

The most important task in the development of crosswalks is the one in charge of determining the semantic correspondence between the elements of the standards to be mapped [12]. This task implies the specification of a mapping between each element in the origin standard and the element that is semantically equivalent to this one in the target standard. For that purpose, it is very important to count on a clear and precise definition of each-standard elements.

Many metadata standards already provide a semantic mapping with standards of related metadata, frequently this mapping appears in form of a table in an annex of the standard. In the process that appears here, at the end of this phase, a mapping table is produced.

2.3 Additional rules for metadata conversion

A crosswalk is a set of transformations that applied to a set of elements in the source metadata standard produce, as a result, an equivalent content in the target standard, which has been properly modified and redistributed to meet the requirements of the analogous elements. Therefore, a completely specified crosswalk must consist of a table of semantic mapping accompanied by a metadata conversion specification. This specification contains the additional transformations required to convert the metadata document whose contents fulfil the source standard into a document whose contents fulfil the target standard. Following subsections present the different metadata conversion problems that may arise and which those additional rules must solve. These rules are usually included as descriptions in an additional column of the mapping table or in an annex document.

2.3.1 Content Conversion

Frequently, metadata standards restrict the contents of each element to a particular data type, range of values or controlled vocabulary. In some cases, two analogous in elements in different standards may have different content restrictions. For example, it could happen that a text value must be transformed into a numerical value or a date value. Therefore specific rules are required to establish the correspondence between the initial element whose values may be specified as free text and a target element whose value is constrained to a controlled vocabulary. Moreover, when mapping two elements restricted to different controlled vocabularies, it is necessary to establish the relationship between values on one-to-one basis.

2.3.2 Element to element mapping

All metadata standards specify a number of properties associated with the definition of each element. For instance, some standards qualify each element as repeatable or non-repeatable and indicate additionally whether this element is mandatory or optional. Others, such as FGDC, incorporate both features into a single property containing a lower and upper bound number of occurrences. A lower bound of zero indicates an optional element, whereas a lower bound of one indicates that the element must occur at least once and thus is mandatory. For crosswalk development, these properties must be taken into careful consideration. The trivial case is the mapping between two elements that share identical properties, e.g. a mandatory non-repeatable element which matches with a mandatory non-repeatable element in target standard. The rest of cases can be classified in the following categories:

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- One to many. In most cases, a one-to-many map is trivial; an occurrence of the source element maps to a single occurrence in the target element. However, there are cases where the mapping requires more explicit resolution. For example, the source standard may contain a non-repeatable *"keywords"* element and according to its definition the content of this element consists of one or more keyword values separated by commas. Nevertheless, this element should match with a repeatable element in the target standard, that is to say, an occurrence for each keyword value. In this case, the mapping requires specialized knowledge of the composition of the source element, and how it expands into multiple target elements. Another interesting case is the mapping of one source element to two unique target elements. For example, a crosswalk for Dublin Core to FGDC standard should map the Dublin Core *"Rights"* element to the *"Access Constraints"* and *"Use Constraints"* elements in FGDC. In this case, special rules must be provided to extract correctly the content of the source element and map it to the corresponding elements in FGDC.
- Many to one. The many-to-one map must specify what to do with the extra elements. If the solution adopted is to map all values of the source element to a single value in the target element, explicit rules are required to specify how concatenate the original values. Alternatively, if the solution is to map a unique value of the source element, with the consequent information loss, a rule must indicate the criteria for this value selection, e.g. the first value or the most recently added.
- Extra elements in source. Another problem arises when a source element does not have any equivalent element in the target standard. Since many metadata standards provide the ability to capture additional information or to define appropriate extensions, a rule must be established to precisely specify how these extra-elements element are handled.
- Unresolved mandatory elements in target. In some cases, mandatory elements in the target standard may have no mapping in the source standard. Because the target requires a value for the mandatory elements, the crosswalk must provide a rule to fill these elements with appropriate values.

2.3.3 Hierarchy

Most metadata standards organize their metadata hierarchically (by means of sections and subsections). The crosswalk must consider the possible differences between the hierarchies of the source and target standards. In the process presented, the mapping table itself shows the elements organized hierarchically in every standard, although it excludes the infinite mapping of those sections, which are recursively defined (e.g. *Citation* section of FGDC) and make the depth of the hierarchy unlimited.

2.4 Automated implementation of crosswalks: the use of style sheets

Taking into account that the metadata standards presented in the introduction section use XML as exchange and presentation format, it has been considered that the most suitable technology to carry out the implementation of crosswalks is by means of XSL (eXtensible Stylesheet Language [10]), whose purpose is precisely the manipulation and transformation of XML. XSL is a language for expressing style sheets that integrates two related languages: a transformation language (XSL Transformations or XSLT); and a formatting language (XSL Formatting Objects) of XML documents, which is comparable to the language CSS (Cascading Style Sheets) for HTML pages. The transformation language (XSLT) provides elements that define rules to transform an XML-document into another XML-document. This second document can use the same set of elements that the original document (it is associated to the same DTD) or can use a completely different set of elements.

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Therefore, the method to make transformations will consist of constructing the style sheet that applied to the original XML-document (in agreement the corresponding standard of metadata) generates as a result an XML-document whose elements fulfil the target standard, and that contains the same information represented in the input document. Next it is detailed the general methodology that has been followed during the construction of style sheets that implement the crosswalks among the different metadata standards. The followed methodology is based on the successive transformation of each section applying the mapping tables that have been defined previously. In particular, the following steps are followed to complete the style sheet:

- Establish the document type declaration that will appear in the output document, and that will include the route (URL) of the DTD corresponding to the target standard.
- Next, for each section to match in the target standard:
  - A template will be created (based on the mapping table) whose pattern is the element (name of section or subsection) in the source standard that generates the corresponding elements in the target. In this template the necessary transformation rules will be applied in order to fulfil the specification with respect to the properties and content in the target standard.
  - Once the first version of the style sheet has been built, it is applied to a XML document that conforms the source standard, and contains values for all the elements belonging to the section previously matched. The style sheet processor (e.g. Java XML parser provided by Oracle at http://technet.oracle.com/) generates as a result a new document. Although this document will not probably validate the DTD corresponding to the target standard (it only contains the sections mapped until this moment), it must be verified that the transformations have been made correctly. By means of a XML edition tool it is possible to visualize the XML document as a tree of nodes, which correspond to the sections, subsections or *PCDATA* tags. Therefore, this tree of nodes is used to check: the absence of a mandatory element; the order of generated elements; and the content constraints. In case of detecting some error, the template must be revised.
  - Additionally, it should be verified that there is not information loss in case the inverse style sheet were applied to the target document. Usually, a crosswalk and the inverse crosswalk are developed in parallel. If there exists some difference between the initial document and this new generated document, the mapping table should be verify the cause of the problem. It may be due to a problem of extra-elements in source standard that has not been resolved by any rule. But if this circumstance does not take place, the XSL template should be checked again.
  - Once it has been proved that the transformation of the last section has been done correctly, the process must be started again for the next section in the source standard until the crosswalk is completely implemented.

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3. DEVELOPED CROSSWALKS

Following the process explained in previous section, several crosswalks (shown in **Fig.1**) have been developed in order to make possible the translation of FGDC metadata into ISO, DC and MIGRA standards. Directed arrows in **Fig.1** represent the existent crosswalks between the source and target standards. Besides, arrows in grey distinguish the real implemented crosswalks from the derived crosswalks, which appear in white and that are obtain from the application of two intermediate crosswalks.

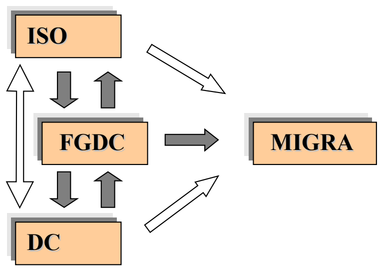

Fig. 1 Developed crosswalks and derived crosswalks.

As an example of crosswalk construction, this section details the transformation from FGDC to ISO. Although the purpose of these two standards is to describe a geographic information resource, they present some important differences.

With respect to the documentation and organization of the standard, FGDC standard is structured in 10 sections (7 main sections and 3 reusable sections) and contain 469 different elements, from which 119 are composite elements (their existence is justified to contain other elements). The syntax of the standard is expressed by means of BNF production rules and addition to this, a definition for the content of each element is also provided. On the opposite, ISO standard uses object-oriented methodology and it is specified by means of the use of UML diagrams, which model the relations and organization of the information captured in this standard. Besides, ISO standard provides a data dictionary that gather the names, descriptions, and domain constraints of all classes and attributes, 509 elements altogether. Given this situation, FGDC main sections could be compared with the ISO packages, which compile the different classes representing the meta-information captured by ISO standard. **Table 1** shows the mapping between sections and packages at a higher level, although this direct mapping does not necessarily exist for deeper levels, where analogous elements are found at different points of the hierarchy.

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FGDC Sections	**ISO Packages**
Main Sections	
Identification information	Identification information (including the references to the sections Constraint information, Maintenance information)
Data quality information	Data quality information
Spatial data organization Information	Spatial representation information
Spatial reference information	Reference System Information
Entity and Attribute Information	Content information
Distribution Information	Distribution Information
Metadata Reference Information	Metadata entity set information (including references to the Constraint information, Maintenance information, and Metadata extension information sections)
	Portrayal catalogue information
	Application schema information
Reusable sections	
Citation information, Contact Information	Citation and responsible party information
Time period information	Extent information

Table 1 Mapping between FGDC and ISO sections

Regarding semantic information, the ISO standard, thanks to its recent appearance more novel and conciliating character, resolves some deficiencies that can be found in FGDC standard. For example, ISO standard provides the data types *Raster* and *Imagery*, whereas in FGDC there is only the first one. Moreover, these standards present slight differences in the terminology. For instance, the element *bounding box* of the FGDC standard contains four coordinate elements, whose short names are *westbc*, *eastbc*, *northbc* and *southbc*. The corresponding element in the ISO standard also contains four elements but this time the short names are *westBL*, *eastBL*, *northBL* and *southBL*. The only difference between these elements consists in a question of terminology, as they are semantically equivalent.

Despite the differences, one of the commonalities in both standards is the fact that the most accepted format for exchange and encoding is XML. The only way to assure that an XML-document is compliant with the standard is validating this document against the DTD provided by the organization that defined the standard. Therefore, a crosswalk implementation based on style sheets is the most accurate solution. The FGD→ISO style sheet that has been created enables the transformation of four of the seven main sections of the FGDC. That includes all the mapping of sections that are mandatory in both standards. The three sections that have not been matched yet are *Spatial_Reference_Information*, *Entity_and_Attribute_Information* and *Data_Quality_Information*. The matching of the two first sections was not possible because their organization and conception were absolutely disparate in both standards. For instance, whereas the names of the sub-sections of *Spatial_Reference_Information* of the FGDC correspond with the different coordinate systems (*Transverse Mercator*, *Mercator*, *Equidistant Conic*...), ISO uses the codes maintained by an organization (e.g. European Petroleum Survey Group), which maintains an updated catalog of coordinate systems, ellipsoids or datums. Concerning the third not paired section, *Data_Quality_Information*, it is not mandatory in both standards and it was decided

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to postpone the mapping since the authors of this paper did not count on enough metadata records with this section completed to study in detail the semantic equivalence.

4. CONCLUSIONS AND FUTURE WORK

This work has presented the process followed to carry out the construction of a series of crosswalks that enable interoperation among some of the most used standards for geographic information metadata, illustrating it with a concrete example of one of the made crosswalks.

Nowadays, most organizations in charge of cataloguing geographic metadata (in accordance with standards like FGDC, CEN or MIGRA) aim at migrating towards the international ISO standard. Apart from that, they are usually asked to provide a more generic description of their resources, that is to say, they are asked to provide a summary view of their specific geographic metadata understandable by general public. This summary view could be the one defined by Dublin Core, a *de facto* standard that is having great acceptance in public administration or in the description of web resources. Under these requirements, the use of different editors to maintain same metadata in each standard does not prove to be the best option. On the contrary, a more sensible option for an institution would be the maintenance of metadata in accordance with a unique standard and produced by a stable cataloguing tool. Then when other views of metadata are required, crosswalks would be applied to obtain the metadata conforming to the demanded standard. Nevertheless, it must be taken into account that these crosswalks must be constructed by means of formalized methods, which enable verification of information transformations and minimize the possible loss of information.

As it has been mentioned before, the process presented has been used for the elaboration of a series of crosswalks, which allow the interoperation between some of the most popular standards in geographic information metadata. There is no notice about the availability of any crosswalks between these standards, neither free nor paying. In fact, some contacts have been established with FGDC and ISO in order to contribute in the creation of the official crosswalk between both standards. In the same way, this research team is going to collaborate in an European project whose one of their objectives is to create a geographic application profile for Dublin Core standard and its mapping to ISO 19115. In this case, the crosswalks already done will serve as a first draft of the project deliverables.

Once these crosswalks have been developed, next step is to prove their utility in the construction of search applications that perform queries against geographic information catalogs. These crosswalks will allow the establishment of restrictions and presentation of results in accordance with a standard selected by the application user on demand. The search client will access the gateway of a network of distributed catalogs, each of them providing metadata according probably to a different standard. However, thanks to the availability of crosswalks, the gateway will be able to translate user requests to the adequate format and present results according to the standard required by each client.

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