A

Collections

A.1 Consistency of the metadata model

Before designing the Knowledge Base presented in section 2.4 to tackle the problem of cataloguing collections, it was studied how metadata records could be synthesized into a minimized model. That is to say, having an initial collection scenario where a metadata record had been created to describe individually (and with consequent redundancies) each component of the collection and the entire collection, we wanted to find a way to transform these initial records into a set of minimized records. Furthermore, our intention was to demonstrate that this transformation function was biyective, i.e. there was a mapping 1:1 between the original and the minimized model. Thus, if a system contained this minimized model, it would be possible to restore the original model when needed.

In order to find out this possible transformation function assuring no loss of information and the possibility of reversibility, we opted for considering metadata records as Abstract Data Types (ADT). There are numerous works in the literature that use algebraic specifications of ADTs, and in general formal specifications, as design tools (Guttag and Horning, 1978, 1980; Horebeek and Lewi, 1989). On one hand, the operations defined for this ADT could facilitate the work of finding this transformation function. And on the other hand, the algebraic specification of this operation could demonstrate the reversibility of this transformation/minimization of the original metadata model.

For the definition of the metadata record ADT we have considered that a metadata record could be defined as a flattened list of ordered elements. This does not constrain the generality of the definition because each metadata element could be a complex structure if necessary. Figure A.1 shows the specification of a metadata record using the algebraic data type language ACT ONE (part of LOTOS (Turner, 1993)).

In this specification, the *sorts* and *opns* parts declare the sorts and specify the operators (constants and nullary operators) along with the signature for the type. The main operations defined for this ADT are *generalization*,

type $metadataRecord$ **is**
formalsorts $metadataElement, natural$
sorts $metadaRecord$
opns
$emptyRecord :\rightarrow metadataRecord$ (* empty record *)
$setEl : metadataRecord, natural, metadataElement \rightarrow metadataRecord$ (* obtains the value of an element *)
$getEl : metadataRecord, natural \rightarrow metadataElement$ (* sets the value of an element *)
$\_ \bigtriangledown \_ : metadataRecord, metadataRecord \rightarrow metadataRecord$ (* extension *)
$\_ \bigtriangleup \_ : metadataRecord, metadataRecord \rightarrow metadataElement$ (* generalization *)
$\_ - \_ : metadataRecord, metadataRecord \rightarrow metadataRecord$ (* subtraction *)
eqns
forall $a, b, c : metadataRecord$
ofsort $metadataRecord$
$(a \bigtriangleup b) \bigtriangleup c = a \bigtriangleup (b \bigtriangleup c)$; (* generalization associative property *)
$a \bigtriangleup b = b \bigtriangleup a$; (* generalization commutative property *)
$a = (a - b) \bigtriangledown (a \bigtriangleup b)$; (* equivalence 1 *)
$a - (a \bigtriangleup b) = a - b$; (* equivalence 2 *)
(* .. Omitted .. *)
endType

Fig. A.1. The *metadataRecord* ADT

subtraction and *extension*, which are represented by the symbols '$\bigtriangleup$', '-' and '$\bigtriangledown$' respectively. The axioms in the *eqns* section clarify the semantic of these operators. Informally, the intention of these operations is the following:

- The *generalization* operation should be used to obtain a new metadata record that contains the common metadata information of a set of metadata records.
- The *subtraction* operation between two records a and b should be used to obtain a new metadata record that discards from a the common meta-information that shares with b.
- And the *extension* operation between two records a and b should be used to obtain a new record that is the extension (union) of records a and b.

Figure A.2 shows the transformation between an original metadata scenario and a minimized scenario by means of *subtraction*, *generalization* and *extension* operations. This figure shows the same notation that was already used for figure 2.8 in section 2.3: MD_is and $MD\_Collection$ are the original metadata records describing the components and the collection; and $MDS\_collection$ and MDS_is are the records of the minimized model stored for the collection and each component. This transformation has the following features: the generalization of MD_is and $MD\_Collection$ generates a *common metadata* record (see later the comment about the subdivision of this *common metadata*); the subtraction of MD_i and *common metadata* generates the MDS_is; and the subtraction of $MD\_Collection$ and *common metadata* generates the *collection-specific metadata* compartment.

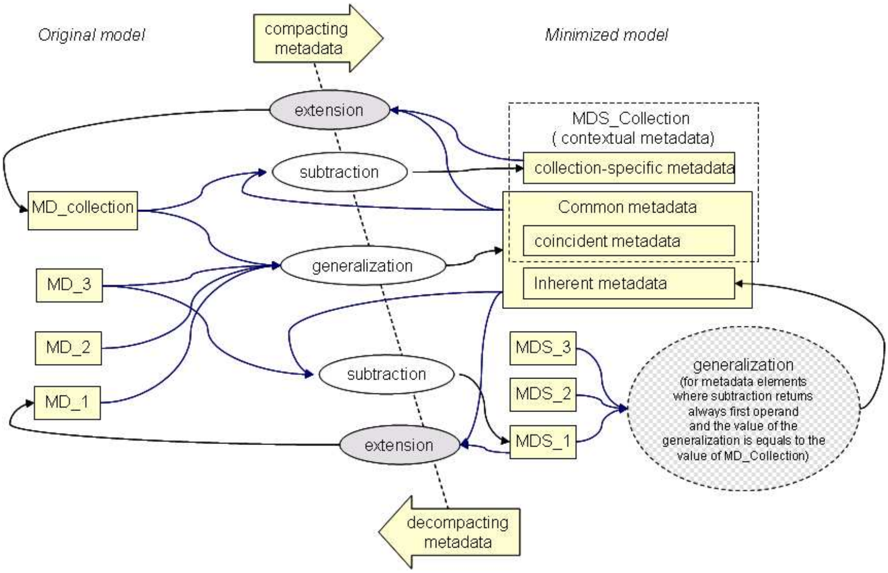

Fig. A.2. Transformation between original and minimized scenario

Theorem: $e_i = s_i \bigtriangledown g$ where
e_i is a metadata record
g is the generalization of a set of records including e_i: $g = (e_1 \bigtriangleup e_2 \bigtriangleup e_3 ... \bigtriangleup e_n)$
and s_i is the not common part of e_i: $s_i = e_i - g$
Proof:
$s_i \bigtriangledown g = (e_i - (e_1 \bigtriangleup e_2 \bigtriangleup e_3 ... \bigtriangleup e_n)) \bigtriangledown (e1 \bigtriangleup e2 \bigtriangleup e3 ... \bigtriangleup en) =$
(* aplying axioms in lines 14 and 15 of specification *)
$(e_i - (e_i \bigtriangleup (e_1 \bigtriangleup e_2 \bigtriangleup .. \bigtriangleup e_{i-1} \bigtriangleup e_{i+1} \bigtriangleup .. \bigtriangleup e_n))) \bigtriangledown (e_i \bigtriangleup (e_1 \bigtriangleup e_2 \bigtriangleup .. \bigtriangleup e_{i-1} \bigtriangleup e_{i+1} \bigtriangleup .. \bigtriangleup e_n)) =$
(* applying axiom in line 17 *)
$(e_i - (e_1 \bigtriangleup e_2 \bigtriangleup .. \bigtriangleup e_{i-1} \bigtriangleup e_{i+1} \bigtriangleup .. \bigtriangleup e_n)) \bigtriangledown (e_i \bigtriangleup (e_1 \bigtriangleup e_2 \bigtriangleup .. \bigtriangleup e_{i-1} \bigtriangleup e_{i+1} \bigtriangleup .. \bigtriangleup e_n)) =$
(* applying axiom in line 16 *)
e_i

Fig. A.3. Derived equation (theorem) from metadata record ADT

The question now is to check whether this transformation is reversible. That is to say, we should prove that the extension between *collection-specific metadata* and *common metadata* obtains again *MD_Collection*; and that the extension between *MDS_i* and *common metadata* obtains again *MD_i*. The answer is that given an implementation of the previous metadata record ADT, we could affirm that the previous hypothesis of the reversible transformation is possible. This is proven by a theorem (property) derived from the axioms in the *eqns* section of the ADT. This theorem could be stated as follows: "having the common meta-information of a set of metadata records (i.e., the generalization of this set of metadata records) and the non-common of each record (subtraction of each initial record and the common metainformation), it is possible to reconstruct every original metadata record". Figure A.3 defines more formally this theorem and its validity through the successive application of axioms.

type $metadataElement$ **is**
formalsorts $dataType$
sorts $metadataElement$
opns
  $emptyElement : \rightarrow metadataElement$ (* empty element *)
  $setValue : dataType \rightarrow metadataElement$
  $getValue : metadataElement \rightarrow dataType$
  $\_ \bigtriangledown \_ : metadataElement, metadataElement \rightarrow metadataElement$ (* extension *)
  $\_ \bigtriangleup \_ : metadataElement, metadataElement \rightarrow metadataElement$ (* generalization *)
  $\_ - \_ : metadataElement, metadataElement \rightarrow metadataElement$ (* subtraction *)
eqns
forall $a, b, c : metadataElement$
ofsort $metadataElement$
  $(a \bigtriangleup b) \bigtriangleup c = a \bigtriangleup (b \bigtriangleup c)$; (* generalization associative property *)
  $a \bigtriangleup b = b \bigtriangleup a$; (* generalization commutative property *)
  $a = (a - b) \bigtriangledown (a \bigtriangleup b)$; (* equivalence 1 *)
  $a - (a \bigtriangleup b) = a - b$; (* equivalence 2 *)
(* .. Omitted .. *)
endType

Fig. A.4. The *metadataElement* ADT

An implementation of this metadata record ADT should be based on the existence of a metadata element ADT with similar operations and semantics. Figure A.4 shows the algebraic specification of the metadata element ADT. And based on this ADT, table A.1 presents the implementation of a metadata record.

Therefore, in order to enable this reversible transformation we should identify possible implementations of the metadata element ADT. These implementations usually depend on the data type of the element value. Some of the most typical implementations that we have identified are:

- The 'default' type implementation (it is shown in table A.2). This implementation is very general a does not bother very much about the *dataType* of the element value. The only restrictions on the *dataType* are the following: there is an equals (=) operator, and the elements can be assigned a *null* value. With respect to minimization in figure A.2, the idea behind this implementation is to detect common values of elements in MD_is and $MD\_Collection$ records. If all these values are equal, a unique value will be stored in the *common metadata* record. Otherwise, the original values are stored in MDS_is and *collection-specific metadata*.

Table A.1. The implementation of the *metadataRecord* ADT

Implementation of operations

Operation	**Implementation**
$emptyRecord$	A metadata record that consist of a list of empty elements.
$getEl(a, n)$	Typical operation in lists
$setEl(a, n, value)$	Typical operation in lists
$a \bigtriangledown b$	$\{getEl(a,1) \bigtriangledown getEl(b,1), getEl(a,2) \bigtriangledown getEl(b,2), \ldots, getEl(a,n) \bigtriangledown getEl(b,n)\}$
$a \bigtriangleup b$	$\{getEl(a,1) \bigtriangleup getEl(b,1), getEl(a,2) \bigtriangleup getEl(b,2), \ldots, getEl(a,n) \bigtriangleup getEl(b,n)\}$
$a - b$	$\{getEl(a,1) - getEl(b,1), getEl(a,2) - getEl(b,2), \ldots, getEl(a,n) - getEl(b,n)\}$

Proof of the equations for this implementation of operations

Equation	**Proof**
$a \bigtriangleup b = b \bigtriangleup a$	This is derived from the 'generalization commutative property' of elements. $a \bigtriangleup b =$ $\{getEl(a,1) \bigtriangleup getEl(b,1), getEl(a,2) \bigtriangleup getEl(b,2), \ldots, getEl(a,n) \bigtriangleup getEl(b,n)\} =$ $\{getEl(b,1) \bigtriangleup getEl(a,1), getEl(b,2) \bigtriangleup getEl(a,2), \ldots, getEl(b,n) \bigtriangleup getEl(a,n)\} =$ $b \bigtriangleup a$
$(a \bigtriangleup b) \bigtriangleup c = a \bigtriangleup (b \bigtriangleup c)$	This is derived from the 'generalization associative property' of elements.
$a = (a - b) \bigtriangledown (a \bigtriangleup b)$	This is derived from the 'equivalence 1' axiom of elements.
$a - (a \bigtriangleup b) = a - b$	This is derived from the 'equivalence 2' axiom of elements.

Table A.2. The 'default' type implementation of the *metadataElement* ADT

Implementation of operations

Operation	**Implementation**
$emptyElement$	$setValue(null)$
$getValue(a)$	Obtain the value.
$setValue(a, value)$	Set the value.
$a \bigtriangledown b$	**if** $getValue(a) = null$ **then return** $setValue(getValue(\mathrm{b}))$ **else return** $setValue(getValue(\mathrm{a}))$
$a \bigtriangleup b$	**if** $getValue(a) = getValue(b)$ **then return** $setValue(getValue(a))$ **else return** $setValue(null)$
$a - b$	**if** $getValue(a) = getValue(b)$ **then return** $setValue(null)$ **else return** $setValue(getValue(a))$

Proof of the equations for this implementation of operations

Equation	**Proof**
$a \bigtriangleup b = b \bigtriangleup a$	Derived from implementation. The order of operands does not have any effect in the result.
$(a \bigtriangleup b) \bigtriangleup c = a \bigtriangleup (b \bigtriangleup c)$	If the values of a, b and c are equal, then the result will be $setValue(getValue(a))$. Otherwise, the result will be $setValue(null)$.
$a = (a - b) \bigtriangledown (a \bigtriangleup b)$	If $getValue(a) = getValue(b)$, then $(a - b) \bigtriangledown (a \bigtriangleup b) = setValue(null) \bigtriangleup a = a$, else $(a - b) \bigtriangledown (a \bigtriangleup b) = a \bigtriangledown setValue(null) = a$.
$a - (a \bigtriangleup b) = a - b$	If $getValue(a) = getValue(b)$, then $a - (a \bigtriangleup b) = a - a = setValue(null)$ and $a - b = a - a = setValue(null)$, else $a - (a \bigtriangleup b) = a - setValue(null) = a$ and $a - b = a$.

- The 'set' type implementation (it is shown in table A.3). This implementation is oriented for elements whose *dataType* is a generic *set* of values. That is to say, this element may have multiple values. The generalization, subtraction and extension operators are implemented as the intersection,

Table A.3. The 'set' type implementation of the *metadataElement* ADT

Implementation of operations

Operation	Implementation
$emptyElement$	$setValue(\varnothing)$
$getValue(a)$	Obtain the 'set of values'.
$setValue(a, value)$	Set the 'set of values'.
$a \bigtriangledown b$	$setValue(getValue(a) \cup getValue(b))$ The result of union of two elements a and b is a new element whose values are the union of values of a and b. Example: $getValue(a) =< v1 >$; $getValue(b) =< v2 >$; $getValue(a \cup b) =< v1, v2 >$
$a \bigtriangleup b$	$setValue(getValue(a) \cap getValue(b))$ The result of the generalization of two metadata elements a and b is a new element whose values are the intersection of values of a and b. Example: $getValue(a) =< v1, v2 >$; $getValue(b) =< v1, v3 >$; $getValue(a \cap b) =< v1 >$
$a - b$	$setValue(getValue(a) - getValue(b))$ The result of the generalization of two metadata records a and b is a new element whose metadata elements values are the subtraction of values of a and b. Example: $getValue(a) =< v1, v2, v3 >$; $getValue(b) =< v3 >$; $getValue(a - b) =< v1, v2 >$

Proof of the equations for this implementation of operations

Equation	Proof
$a \bigtriangleup b = b \bigtriangleup a$	Derived from the implementation. The intersection of sets is commutative.
$(a \bigtriangleup b) \bigtriangleup c = a \bigtriangleup (b \bigtriangleup c)$	Derived from the implementation. The intersection of sets is associative.
$a = (a - b) \bigtriangledown (a \bigtriangleup b)$	Derived from the implementation. The intersection, subtraction and union of sets comply with this equivalence.
$a - (a \bigtriangleup b) = a - b$	Derived from the implementation. The intersection, subtraction and union of sets comply with this equivalence.

subtraction and union of the sets of values corresponding to the elements implied in the operation. An example of an element for which this implementation could apply is a *keywords* element (e.g., the *descriptivekeywords* attribute of the *MD_Identification* class in ISO 19115 (ISO, 2003a)) that contains a set of values describing the topics covered by the resource.

- The 'string' type implementation (it is shown in table A.4). This implementation for elements whose *dataType* is a *string*. It is assumed that this *dataType* has the following features: it can be assigned a *null* value; there is an operation for the concatenation of strings denoted as $\_ \circ \_$; the $commonPrefix(string, string)$ operation returns a new *string* with the common prefix of the two *strings*; and the $removePrefix(string, string)$ operation returns a new string removing from the first argument the beginning characters that correspond to the second argument (if it is really a prefix of the first argument). An example of an element for which this implementation could apply is the *title* element (e.g., the *title* attribute of the *CI_Citation* class in ISO 19115). Usually, a generic title is given for a collection and each component is entitled with the concatenation of the generic title plus the code of a specific dataset component (e.g., the numbering of a tile). Extension, subtraction and generalization operations are implemented in order to obtain these concatenations, suffixes and prefixes.

Table A.4. The 'string' type implementation of the *metadataElement* ADT

Implementation of operations

Operation	**Implementation**
$emptyElement$	$setValue(null)$
$getValue(a)$	Obtain the value.
$setValue(a, value)$	Set the value.
$a \bigtriangledown b$	$setValue(getValue(b) \circ getValue(a))$ Example:$getValue(a)=$ "A:28"; $getValue(b)=$"National Topographic Map. "; $getValue(a \bigtriangledown b)=$"National Topographic Map. A:28"
$a \bigtriangleup b$	$setValue(commonPrefix(getValue(a), getValue(b)))$ Example:$getValue(a)=$"National Topographic Map. A:28"; $getValue(b)=$"National Topographic Map. B:29"; $getValue(a \bigtriangleup b)=$"National Topographic Map. "
$a - b$	$setValue(removePrefix(getValue(a), commonPrefix(getValue(a)$ $, getValue(b))))$ Example:$getValue(a)=$"National Topographic Map. A:28"; $getValue(b)=$"National Topographic Map. ";$getValue(a - b)=$"A:28"

Proof of the equations for this implementation of operations

Equation	**Proof**
$a \bigtriangleup b = b \bigtriangleup a$	$a \bigtriangleup b = setValue(commonPrefix(getValue(a), getValue(b))) =$ $setValue(commonPrefix(getValue(b), getValue(a))) = b \bigtriangleup a$
$(a \bigtriangleup b) \bigtriangleup c = a \bigtriangleup (b \bigtriangleup c)$	$(a \bigtriangleup b) \bigtriangleup c =$ $setValue(commonPrefix(getValue(a), getValue(b))) \bigtriangleup c =$ $setValue(commonPrefix(commonPrefix(getValue(a),$ $getValue(b)), getValue(c))) =$ $setValue(commonPrefix(getValue(a), getValue(b), getValue(c)));$ $a \bigtriangleup (b \bigtriangleup c) =$ $a \bigtriangleup setValue(commonPrefix(getValue(b), getValue(c))) =$ $setValue(commonPrefix(getValue(a), commonPrefix($ $getValue(b), getValue(c)))) =$ $setValue(commonPrefix(getValue(a), getValue(b), getValue(c)));$
$a = (a - b) \bigtriangledown (a \bigtriangleup b)$	$(a - b) \bigtriangledown (a \bigtriangleup b) =$ $setValue(removePrefix(getValue(a), commonPrefix(getValue(a)$ $, getValue(b))) \bigtriangledown setValue(commonPrefix(getValue(a)$ $, getValue(b))) =$ $setValue(commonPrefix(getValue(a), getValue(b)) \circ$ $removePrefix(getValue(a), commonPrefix(getValue(a)$ $, getValue(b)))) =$ $setValue(getValue(a)) = a$ Example: $getValue(a) =$"title 1";$getValue(b) =$"title 2"; $getValue(a - b) =$"1";$getValue(a \bigtriangleup b) =$"title "; $getValue((a - b) \bigtriangledown (a \bigtriangleup b)) =$"title "$\circ$"1"="title 1"$= getValue(a)$
$a - (a \bigtriangleup b) = a - b$	$a - (a \bigtriangleup b) =$ $a - setValue(commonPrefix(getValue(a), getValue(b))) =$ $setValue(removePrefix(getValue(a), commonPrefix($ $getValue(a), commonPrefix(getValue(a), getValue(b))))) =$ $setValue(removePrefix(getValue(a), commonPrefix($ $getValue(a), getValue(b)))) =$ $a - b$

- The 'aggregation' type implementation (it is shown in table A.5). This implementation is oriented for *dataTypes* where an aggregated function can be defined. Examples of these aggregated functions are the maximum, minimum, sum, or average of numbers. But this is also applicable to other more sophisticated functions operating over 2D geometries or time intervals. This is particularly interesting for elements such as the *geographic location* of a resource, which is usually represented by means of a bounding box. In such a case, the *geographic location* of the collection can be com-

Table A.5. The 'aggregation' type implementation of the *metadataElement* ADT

Implementation of operations

Operation	Implementation
$emptyElement$	$setValue(null)$
$getValue(a)$	Obtain the value.
$setValue(a, value)$	Set the value.
$a \bigtriangledown b$	$setValue(getValue(a))$ It returns always the first operand.
$a \bigtriangleup b$	$setValue(aggFunction(getValue(a), getValue(b)))$
$a - b$	$setValue(getValue(a))$ It returns always the first operand.

Proof of the equations for this implementation of operations

$a \bigtriangleup b = b \bigtriangleup a$	The aggregated function is conmutative.
$(a \bigtriangleup b) \bigtriangleup c = a \bigtriangleup (b \bigtriangleup c)$	The aggregated function is associative.
$a = (a - b) \bigtriangledown (a \bigtriangleup b)$	$(a - b) \bigtriangledown (a \bigtriangleup b) = a \bigtriangledown (a \bigtriangleup b) = a$
$a - (a \bigtriangleup b) = a - b$	$a - (a \bigtriangleup b) = a$ $a - b = a$

puted as the envelope or minimum bounding box that covers the bounding boxes of the components (see figure A.5). This case is also similar to the *temporal extent* element describing the time interval for which a resource is valid. The temporal extent of the collection is usually defined as the minimum time interval that covers the *temporal extent* of each component in the collection. This aggregated function, denoted as *aggFunction* in table A.5, is used as the implementation of the generalization.

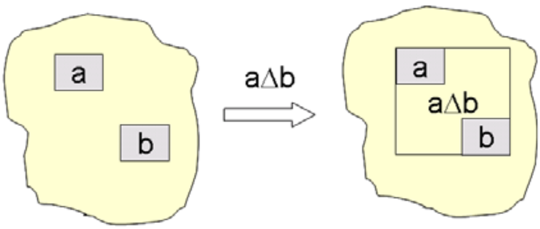

Fig. A.5. Generalization (envelope) of bounding boxes

As a conclusion, a system using implementations of the *metadataElement* ADT could perform this reversible transformation. Given an original metadata scenario (with all the metadata records), the user should decide what kind of *metadataElement* implementation corresponds with each element of the metadata standard used. And then, the system could minimize the original metadata. Obviously, the user should select those implementations that are more beneficial for minimization. For instance, if the user detects that all the values of the element *abstract* are identical, he should opt for a 'default' type implementation. In contrast, if he detects that the *keyword* element can have multiple values and, apart from some exceptions, most of them are identical, he should opt for a 'set' type implementation.

This algebraic approach is interesting for such a reversible system. But being realistic, the minimization of an original scenario rarely takes place. That is precisely what metadata creators are trying to avoid. They want to create uniquely a minimized model that could be expanded to the complete metadata model in demand. Furthermore, the configuration of the system implying the selection of the appropriate implementation for each element should result really tedious. Thus, the Metadata Knowledge Base presented in chapter 2 is only focused in the reverse process, i.e. obtaining complete metadata from a minimized model and reducing the configuration tasks as much as possible. Notwithstanding that, this previous study with algebraic specifications of metadata records has contributed in important aspects of the knowledge base:

- The metadata stored in the knowledge base corresponds with a minimization scenario where the implementations allowed for each element e are:
  1. An implementation verifying that the generalization of the element e among
     $MD\_Collection$ and MD_is is equals to the value of e in $MD\_Collection$:
     $getEl(commonMetadata, e) = getEl(MD\_Collection, e) \triangle getEl(MD\_1, e) \triangle \ldots \triangle getEl(MD\_n, e) = getEl(MD\_collection, e)$.
     Thus, the value of e within *common metadata* contains the original value of
     $MD\_Collection$. An example of this implementation is the selection of a 'string' type implementation for the *title* element whenever all the component titles have as prefix the collection title.
  2. Otherwise, a 'default' type implementation must be used. Thus, when all the records do not contain the same value for this element, the value contained within *common metadata* compartment will be null and the value in *collection-specific metadata* will contain the original value of *MD_Collection*.
- There is a subgroup of the first allowed types of implementations that have interesting properties. This group of implementations is referred to as implementations producing *inherent metadata*. These implementations add two characteristics. Firstly, the subtraction operation always return the first operand ($a - b = a$). And secondly, the generalization of the element e in MD_is is equals to the value of e in $MD\_Collection$:
  $getEl(MD\_1, e) \triangle \ldots \triangle getEl(MD\_n, e) = getEl(MD\_Collection, e) \triangle getEl(MD\_1, e) \triangle \ldots \triangle getEl(MD\_n, e) = getEl(MD\_collection, e)$.
  Looking back to figure A.2 we realize that these implementations do not minimize the values (the values of these elements in the left side or in the right side are identical). Thus, it is not necessary to store the original value of the element in the *common metadata* compartment. We can compute this value when needed. Finally, according to the possible existence of

these implementations, the *common metadata* in figure A.2 is divided into: *inherent metadata* containing the result of the generalization of this special subgroup of elements; and *coincident metadata* containing the rest of non-empty metadata.

- The metadata records describing the components correspond with the MDS_i depicted in figure A.2.
- The metadata record describing the collection ($MDS\_Collection$) contains the value for each element e as follows:
  - If it has a non-null value in *coincident metadata*, this value is stored in $MDS\_Collection$.
  - Otherwise, if the element has not been classified as producing *inherent metadata*, the value contained in $MDS\_Collection$ corresponds to the value in *collection-specific* metadata.

  That is to say, all the values of elements in $MDS\_Collection$ correspond to a part of the original values in $MD\_Collection$. The rest of original values are obtained by computing and adding the *inherent metadata* when needed. All the element values that are needed to restore the MDS_i (they were initially stored in *common metadata*) are in $MDS\_Collection$ too.
- The functions specified in the *_wholeInferredValuesSpecification* would correspond with the generalization operations of those elements classified as producing inherent metadata. We do not store the generalization of other elements because we are not going to minimize an original scenario, we are only interested in the reverse process and we already have the *coincident metadata*.
- The functions specified in the *_partDerivedValuesSpecification* attribute of *KB_AggregationRelationType* would correspond to the different implementations of the extension operation. The specification of the extension operation is not necessary for elements with a 'default' type implementation or for those elements classified as producing *inherent metadata*. In the first case, this extension operation is considered as a default mechanism: the inheritance by default of component records with respect to the collection record. That is to say, if a component has not got a value, it will try to obtain it from the collection record. In the second case, the components are also supposed to have the original value without further processing (the subtraction operation always returns the first operand for these implementations producing *inherent metadata*). This means that there can not be functions in both *_wholeInferredValuesSpecification* and *_partDerivedValuesSpecification* to obtain a value for the same element.
- We should assure that the functions specified in *_partDerivedValuesSpecifi cation* and *_wholeInferredValuesSpecification* comply with the equations in the *metadataElement* ADT. For instance, the functions specified in *_wholeInferredValuesSpecification* must be commutative and associative. Additionally, although we do not specify all the operations (e.g., subtraction) it must be assured that we can find associated functions that comply with the specified equations.

- The process of establishing a mapping between an element and the appropriate implementation of the *metadataElement* ADT aids to identify the metadata inference that a concrete aggregation relation type should support.

A.2 Metadata Inference

A.2.1 Generation of complete values

KB_Metadata.getCompleteValues

```
/**
  * Returns the list of complete XML instances </p>
  * If _completeValues is not precalculated, it is generated again</p>
  * For the automatic generation, it uses the methods getWholeInferredValues and
  * getValuesBeingPart, which climb up and down through the whole part hierarchy
  * respectively.</p>
  */
public List getCompleteValues(){
  if (_completeValues == null)
  {
    // completeValues must be computed
    _completeValues = new LinkedList();
    // Obtain the values of the record acting as part
    List valuesBeingPart = getValuesBeingPart();
    // Obtain the values of the record acting as whole
    XML wholeInferredValues = null;
    if (getPartRelation()!=null)
      wholeInferredValues = getPartRelation().getWholeInferredValues();
    // Apply priorities
    // 2nd priority. The whole-inferred values have lower priority
    // 1st priority. The values obtained acting as part have higher priority
    ListIterator it = valuesBeingPart.listIterator();
    while(it.hasNext()) {
      XML completeXML = null;
      if (wholeInferredValues!=null){
        completeXML = wholeInferredValues.getCopy();
        completeXML.update( (XML) it.next());
      } else
        completeXML = (XML) it.next();
      _completeValues.add(completeXML);
    }
  }
  return _completeValues;
}
```

KB_Metadata.getValuesBeingWhole

```
/**
  * Returns the metadata of this record, acting this record as a collection
  * metadata record
  */
public XML getValuesBeingWhole() {
  // Obtain whole inferred values
  XML wholeInferredValues = null;
  if (getPartRelation()!=null)
    wholeInferredValues = getPartRelation().getWholeInferredValues();
  // apply priorities
  // 2nd priority. The whole-inferred values have lowest priority
  // 1st priority. The specific values have higher priority
  if (wholeInferredValues!=null) {
```

```
    wholeInferredValues.update(getSpecificValues());
    return wholeInferredValues;
  } else
    return getSpecificValues().getCopy();
}
```

KB_Metadata.getValuesBeingPart

```
/**
  * Returns the metadata of this record, acting this record as a part of
  * a collection
  * It takes into account that :a record may belong to several collections
  * and that a record may have several grandparents
  */
public List getValuesBeingPart(){
  List results = new LinkedList(); // initialization of list of results
  if ((getWholeRelations()==null)||(getWholeRelations().isEmpty()))
    results.add(getSpecificValues().getCopy());
  else {
   // a record may belong to several collections
   ListIterator it = getWholeRelations().listIterator();
   while (it.hasNext())
   {
     KB_AggregationRelation rel = (KB_AggregationRelation) it.next();
     // Obtain inherited XMLs (a record may have only one parent but several
     // grandparents)
     List partInheritedValues = rel.getPartInheritedValues();
     // Obtain derived XMLs (one for each possible inherited XML)
     List partDerivedValues = rel.getPartDerivedValues(getSpecificValues());
     // Apply priorities
     ListIterator itInh = partInheritedValues.listIterator();
     ListIterator itDer = partDerivedValues.listIterator();
     while (itInh.hasNext()&&itDer.hasNext())
     {
       // 3rd priority. Inherited values have the lowest priority
       XML result = (XML)itInh.next();
       // 2nd priority. Specific values have middle priority
       result.update(getSpecificValues());
       // 1st priority. Derived values have highest priority
       result.update( (XML) itDer.next());
       // add result to the list of results
       results.add(result);
     }
   }
  }
  return results;
}
```

KB_AggregationRelation.getWholeInferredValues

```
/**
  * It returns the whole inferred values.
  * If _wholeInferredValues is not precalculated, it is generated again</p>
  * It climbs down through the whole-part hierarchy
  */
public XML getWholeInferredValues() {
   if (_wholeInferredValues == null)
   {
      // _wholeInferredValues must be calculated
      if ((getParts()!=null)&&(!getParts().isEmpty())
           && (getWholeInferredValuesSpecification()!=null)
           && (!getWholeInferredValuesSpecification().isEmpty()))
      {
          List parts = getParts();
          // find the values to merge
          List valuesToMerge = new LinkedList();
```

```
            ListIterator it = parts.listIterator();
            while (it.hasNext())
               valuesToMerge.add( ((KB_Metadata) it.next()).getValuesBeingWhole());
            // apply wholeInferredValuesSpecification
            _wholeInferredValues = XML.inferWholeValues(valuesToMerge
                      ,getWholeInferredValuesSpecification());
         }
     }
     return _wholeInferredValues;
  }
```

KB_AggregationRelation.getPartInheritedValues

```
  /**
    * It returns the list of inherited XMLs
    * If _partInheritedValues is not precalculated, it is generated again</p>
    * It climbs up through the whole-part hierarchy
    */
  public List getPartInheritedValues(){
    if (_partInheritedValues==null)
      // _partInheritedValues must be calculated
      _partInheritedValues = getWhole().getValuesBeingPart();
    // it returns a copy of each XML
    List result = new LinkedList();
    ListIterator it = _partInheritedValues.listIterator();
    while (it.hasNext())
      result.add( ((XML)it.next()).getCopy());
    return result;
  }
```

KB_AggregationRelation.getPartDerivedValues

```
  /**
   * It returns the part derived values
   * @param part specific values of the metadata record
   */
  public List getPartDerivedValues(XML part) {
    List results = new LinkedList();
    List partInheritedValuesList = this.getPartInheritedValues();
    ListIterator it = partInheritedValuesList.listIterator();
    while ( it.hasNext())
    {
      XML partInheritedValues = (XML) it.next();
      results.add(XML.deriveValues(partInheritedValues,part
                      ,getPartDerivedValuesSpecification()));
    }
    return results;
  }
```

A.2.2 Update of whole-part hierarchy

KB_Metadata.updateWholePartHierarchy

```
  /** Update the whole-part hierarchy */
  public void updateWholePartHierarchy() {
    updateWhole(); // update parents
    updateParts(); // update children
    updateCompleteValues(); // update complete values
  }
```

KB_Metadata.updateWholes

```
/** Update parents */
public void updateWholes() {
  if ((getWholeRelations()!=null)&&(!getWholeRelations().isEmpty()))
  {
    // update the whole-inferred values for each relation where
    // 'this' is included
    ListIterator it = getWholeRelations().listIterator();
    ((KB_AggregationRelation)it.next()).updateWholeInferredValues();
  }
}
```

KB_Metadata.updateParts

```
/** Update parts */
public void updateParts() {
  if (getPartRelation()!=null)
    // update the partInheritedValues stored in the partRelation
    getPartRelation().updatePartInheritedValues();
}
```

KB_Metadata.updateCompleteValues

```
/** It provokes the recalculation of complete valures */
public void updateCompleteValues() {
  _completeValues = null;
  getCompleteValues();
}
```

KB_AggregationRelation.updateWholeInferredValues

```
/**
  * It implies the recalculation of _wholeInferredValues of this relation
  * and higher level relations
  * It is invoked from KB_Metadata.updateWhole when the specific values of a
  * metadata record have been updated, or this record has been added to a
  * collection.
  * It also implies the recalculation of completeValues in the ascending hierarchy
  */
public void updateWholeInferredValues() {
  if ((getWholeInferredValuesSpecification()!=null)&&
        (!getWholeInferredValuesSpecification().isEmpty()))
  {
    // prior value is invalidated
    _wholeInferredValues=null;
    // climb up through the whole-part hierarchy
    getWhole().updateWholes();
    // Then, climb down through the whole-part hierarchy to recalculate complete
    // values
    getWhole().updateCompleteValues();
  }
}
```

KB_AggregationRelation.updatePartInheritedValues

```
/**
  * It implies the recalculation of _partInherited values of this relation and lower
  * relations
  * It is invoked from KB_Metadata.updateParts when the specific values of a
  * metadata record have been updated, or this record has been added to a
  * collection
  */
public void updatePartInheritedValues() {
  // prior value is invalidated
  _partInheritedValues = null;
  // climb down through the whole-part hierarchy
```

```
    ListIterator it = getParts().listIterator();
    KB_Metadata part = null;
    while(it.hasNext()) {
       part = (KB_Metadata) it.next();
       // recursive invocation
       part.updateParts();
       // then, climb up updating the complete values
       part.updateCompleteValues();
    }
  }
```

A.2.3 Example of a *wholeInferredValues* specification

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<xsl:stylesheet version="1.0"
xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
       xmlns:iso19115="http://www.isotc211.org/iso19115"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
exclude-result-prefixes="iso19115">

<xsl:output method="xml" indent="yes" encoding="ISO-8859-1"/>

<xsl:template match="/">
  <xsl:apply-templates select="components"/>
  <!-- components tag groups the individual metadata records, i.e. MD_Metadata
       tags -->
</xsl:template>

<xsl:template match="components">
 <!-- check whether the metadata of a component has geographic elements -->
 <xsl:if test="./MD_Metadata/identificationInfo/*/extent/geographicElement/*/
              northBoundLatitude">
  <!-- generate the tags of XML output -->
  <xsl:element name="iso19115:MD_Metadata">
   <xsl:element name="identificationInfo">
    <xsl:element name="iso19115:MD_DataIdentification">
     <xsl:element name="extent">
      <xsl:element name="geographicElement">
       <xsl:element name="iso19115:EX_GeographicBoundingBox">
        <xsl:variable name="total" select="count(./MD_Metadata/identificationInfo/
          */extent/geographicElement/EX_GeographicBoundingBox)"/>
        <!-- generate westBoundLongitude -->
        <xsl:element name="westBoundLongitude">
         <xsl:call-template name="agg">
          <xsl:with-param name="plist" select=
"./MD_Metadata/identificationInfo/*/extent/geographicElement/EX_GeographicBoundingBox/
              westBoundLongitude"/>
          <xsl:with-param name="index" select="1"/>
          <xsl:with-param name="total" select="$total"/>
          <xsl:with-param name="aggFunction" select="'min'"/>
         </xsl:call-template>
        </xsl:element>
        <!-- generate eastBoundLongitude -->
         <xsl:element name="eastBoundLongitude">
         <xsl:call-template name="agg">
          <xsl:with-param name="plist" select=
"./MD_Metadata/identificationInfo/*/extent/geographicElement/EX_GeographicBoundingBox/
              eastBoundLongitude"/>
          <xsl:with-param name="index" select="1"/>
          <xsl:with-param name="total" select="$total"/>
          <xsl:with-param name="aggFunction" select="'max'"/>
         </xsl:call-template>
        </xsl:element>
        <!-- generate southBoundLatitude -->
```

```
        <xsl:element name="southBoundLatitude">
         <xsl:call-template name="agg">
          <xsl:with-param name="plist" select=
"./MD_Metadata/identificationInfo/*/extent/geographicElement/EX_GeographicBoundingBox/
              southBoundLatitude"/>
          <xsl:with-param name="index" select="1"/>
          <xsl:with-param name="total" select="$total"/>
          <xsl:with-param name="aggFunction" select="'min'"/>
         </xsl:call-template>
        </xsl:element>
        <!-- generate northBoundLatitude -->
        <xsl:element name="northBoundLatitude">
         <xsl:call-template name="agg">
          <xsl:with-param name="plist" select=
"./MD_Metadata/identificationInfo/*/extent/geographicElement/EX_GeographicBoundingBox/
              northBoundLatitude"/>
          <xsl:with-param name="index" select="1"/>
          <xsl:with-param name="total" select="$total"/>
          <xsl:with-param name="aggFunction" select="'max'"/>
         </xsl:call-template>
        </xsl:element>
        <!-- generate end tags of XML output -->
       </xsl:element> <!-- EX_GeographicBoundingBox -->
      </xsl:element> <!-- geographicElement -->
     </xsl:element> <!-- extent -->
    </xsl:element>  <!-- iso19115:MD_DataIdentification -->
   </xsl:element>  <!-- identificationInfo-->
  </xsl:element> <!--/iso19115:MD_Metadata-->
 </xsl:if>
</xsl:template>

<!-- This template applies the aggregated functions, max or min,
over a list of parameter values --> <xsl:template name="agg">
  <xsl:param name="plist" select="/.." /> <!-- list of coordinate values -->
  <xsl:param name="index"/> <!-- index of element in the list that it is compared -->
  <xsl:param name="total"/> <!-- total number of elements in the list -->
  <xsl:param name="aggFunction"/> <!-- aggregated function -->
  <xsl:choose>
    <xsl:when test="$index=$total">
      <!-- base case -->
      <xsl:value-of select="$plist[$index]"/>
    </xsl:when>
    <xsl:otherwise>
      <!-- recursive step -->
      <xsl:variable name="aggValue">
        <xsl:call-template name="agg">
          <xsl:with-param name="plist" select="$plist"/>
          <xsl:with-param name="index" select="$index + 1"/>
          <xsl:with-param name="total" select="$total"/>
          <xsl:with-param name="aggFunction" select="$aggFunction"/>
        </xsl:call-template>
      </xsl:variable>
      <!-- select the aggregation function that must be applied -->
      <xsl:choose>
        <xsl:when test="$aggFunction = 'max'">
          <xsl:choose>
            <xsl:when test="$aggValue &gt; $plist[$index]">
              <xsl:value-of select="$aggValue"/>
            </xsl:when>
            <xsl:otherwise>
              <xsl:value-of select="$plist[$index]"/>
            </xsl:otherwise>
          </xsl:choose>
        </xsl:when>
        <xsl:when test="$aggFunction = 'min'">
          <xsl:choose>
            <xsl:when test="$aggValue &lt; $plist[$index]">
```

```
              <xsl:value-of select="$aggValue"/>
            </xsl:when>
            <xsl:otherwise>
              <xsl:value-of select="$plist[$index]"/>
            </xsl:otherwise>
          </xsl:choose>
        </xsl:when>
      </xsl:choose>
    </xsl:otherwise>
  </xsl:choose>
</xsl:template>

</xsl:stylesheet>
```

B

Crosswalks

B.1 CSDGM→ISO 19115 stylesheet

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<xsl:stylesheet version="1.0"
     xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
     xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
     xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
     xmlns:dc="http://purl.org/dc/elements/1.1"
     xmlns:dcterms="http://purl.org/dc/terms"
     xmlns:iso19115="http://www.isotc211.org/iso19115/"
     xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
    <xsl:output method="xml" indent="yes" encoding="ISO-8859-1"/>
    <xsl:template match="/">
        <xsl:apply-templates select="metadata"/>
    </xsl:template>
    <!-- conversion of main METADATA section into MD_METADATA -->
    <xsl:template match="metadata">
        <xsl:element name="iso19115:MD_Metadata">
            <!--    ISO19115:_MD_IDENTIFICATION-->
            <xsl:element name="identificationInfo">
                <xsl:apply-templates select="idinfo"/>
            </xsl:element>
        ...
        </xsl:element>
    </xsl:template>
    <!-- conversion of IDINFO section into MD_IDENTIFICATION -->
    <xsl:template match="idinfo">
        <xsl:element name="iso19115:_MD_Identification">
            <xsl:attribute name="xsi:type">iso19115:MD_DataIdentification
            </xsl:attribute>
            <!--  conversion of CITATION subsection -->
            <xsl:element name="citation">
                <xsl:apply-templates select="citation/citeinfo"/>
            </xsl:element>
                        ...
        </xsl:element>
    </xsl:template>
    <!-- template for CITATION element -->
    <xsl:template match="citation/citeinfo | identAuth/citeinfo">
        <!--  TITLE -->
        <xsl:element name="title">
            <xsl:value-of select="title"/>
        </xsl:element>
        <!-- there is no ALTERNATETITLE in FGDC -->
```

```
<!-- conversion of DATE element (mandatory). When empty, it is generated
     by default -->
<xsl:element name="date">
    <xsl:element name="date">
        <xsl:choose>
            <xsl:when test="./pubdate!=’’">
                <xsl:value-of select="pubdate"/>
            </xsl:when>
            <xsl:otherwise>0001-01-01</xsl:otherwise>
        </xsl:choose>
    </xsl:element>
    <xsl:element name="dateType">
        <xsl:text>publication</xsl:text>
    </xsl:element>
</xsl:element>
<!-- conversion of EDITION element -->
<xsl:if test="edition">
    <xsl:element name="edition">
        <xsl:value-of select="./edition"/>
    </xsl:element>
</xsl:if>
<!-- there is no EDITIONDATE element in FGDC -->
<!-- generation of IDENTIFIER element -->
<xsl:if test="citId">
    <xsl:element name="identifier">
        <xsl:element name="code">
            <xsl:value-of select="./citId"/>
        </xsl:element>
    </xsl:element>
</xsl:if>
<!-- conversion of ORIGINATOR into CITEDRESPONSIBLEPARTY element
     (role="originator") -->
<xsl:for-each select="origin">
    <xsl:if test="normalize-space(.)!=’’">
        <xsl:element name="citedResponsibleParty">
            <xsl:element name="organisationName">
                <xsl:value-of select="."/>
            </xsl:element>
            <xsl:if test="/metadata/idinfo/citation/citeinfo[onlink]">
                <xsl:element name="contactInfo">
                    <xsl:element name="onlineResource">
                        <xsl:element name="linkage">
                            <xsl:value-of select="../onlink"/>
                        </xsl:element>
                    </xsl:element>
                </xsl:element>
            </xsl:if>
            <xsl:element name="role">
                <xsl:text>originator</xsl:text>
            </xsl:element>
        </xsl:element>
    </xsl:if>
</xsl:for-each>
<!-- conversion of PUBLISHER into CITEDRESPONSIBLEPARTY element
     (role="publisher") -->
<xsl:if test="/metadata/idinfo/citation/citeinfo[pubinfo]">
    <xsl:element name="citedResponsibleParty">
        <xsl:element name="organisationName">
            <xsl:value-of select="./pubinfo/publish"/>
        </xsl:element>
        <xsl:element name="contactInfo">
            <xsl:element name="address">
                <xsl:element name="city">
                    <xsl:value-of select="./pubinfo/pubplace"/>
                </xsl:element>
            </xsl:element>
        </xsl:element>
```

```
                <xsl:element name="role">
                    <xsl:text>publisher</xsl:text>
                </xsl:element>
            </xsl:element>
        </xsl:if>
        <!-- conversion of GEOFORM into PRESENTATIONFORM -->
        <xsl:if test="geoform">
            <xsl:element name="presentationForm">
                <xsl:value-of select="./geoform"/>
            </xsl:element>
        </xsl:if>
        <!-- conversion of SERINFO into SERIES -->
        <xsl:if test="serinfo">
            <xsl:element name="series">
                <!-- the subelements of SERINFO are mandatory but optional in ISO
                     CI_Series -->
                <xsl:element name="name">
                    <xsl:value-of select="./serinfo/sername"/>
                </xsl:element>
                <xsl:element name="issueIdentification">
                    <xsl:value-of select="./serinfo/issue"/>
                </xsl:element>
            </xsl:element>
        </xsl:if>
        <!-- conversion of OTHERCIT into OTHERCITATIONDETAILS-->
        <xsl:if test="othercit">
            <xsl:element name="otherCitationDetails">
                <xsl:value-of select="./othercit"/>
            </xsl:element>
        </xsl:if>
        <!-- conversion of ISBN -->
        <xsl:if test="isbn">
            <xsl:element name="ISBN">
                <xsl:value-of select="./isbn"/>
            </xsl:element>
        </xsl:if>
        <!-- conversion of ISSN -->
        <xsl:if test="issn">
            <xsl:element name="ISSN">
                <xsl:value-of select="./issn"/>
            </xsl:element>
        </xsl:if>
    </xsl:template>
    <!--...-->
</xsl:stylesheet>
```

B.2 ISO 19115→DC stylesheet

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<xsl:stylesheet
      version="1.0" xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
      xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
      xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
      xmlns:dc="http://purl.org/dc/elements/1.1"
      xmlns:dcterms="http://purl.org/dc/terms"
      xmlns:iso19115="http://www.isotc211.org/iso19115/"
      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <xsl:output method="xml" indent="yes" encoding="ISO-8859-1"/>
  ...
  <xsl:template match="/">
    <xsl:apply-templates select="iso19115:MD_Metadata"/>
  </xsl:template>
  <xsl:template match="iso19115:MD_Metadata">
    <xsl:element name="rdf:RDF">
```

```
      <xsl:element name="rdf:Description">
    <!-- CONVERSION OF TITLE ELEMENT: For each occurrence of attribute
     title in CI_Citation entity, a DC:TITLE occurrence will be generated.-->
      <xsl:for-each select="./iso19115:_MD_Identification/citation/title">
        <xsl:element name="dc:title">
          <xsl:value-of select="normalize-space(.)"/>
        </xsl:element>
      </xsl:for-each>
    ...
    <!-- CONVERSION OF CREATOR ELEMENT: Each occurrence of MD_Metadata.identificationInfo
     .pointOfContact (CI_ResponsibleParty entity with role="originator") must be mapped
     to a single value of DC:CREATOR. If the CI_ResponsibleParty has been correctly
     completed, organisationName or individualName or positionName must contain a non-null
     value. The value of these attributes (in the order previously mentioned) will be
     used to create a DC:CREATOR element. -->
      <xsl:for-each select="./iso19115:_MD_Identification/pointOfContact">
        <xsl:if test="normalize-space(./role/CI_RoleCode_CodeList)='originator'">
          <xsl:element name="dc:creator">
            <xsl:choose>
              <xsl:when test="./organisationName">
                <xsl:value-of select="./organisationName"/>
              </xsl:when>
              <xsl:when test="./individualName">
                <xsl:value-of select="./individualName"/>
              </xsl:when>
              <xsl:when test="./positionName">
                <xsl:value-of select="./positionName"/>
              </xsl:when>
              <xsl:otherwise><!-- This should never happen. -->
              </xsl:otherwise>
            </xsl:choose>
          </xsl:element>
        </xsl:if>
      </xsl:for-each>
      ...
      </xsl:element>
    </xsl:element>
  </xsl:template>
</xsl:stylesheet>
```

B.3 DC→ISO 19115 stylesheet

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<xsl:stylesheet
       version="1.0" xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
       xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
       xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
       xmlns:dc="http://purl.org/dc/elements/1.1"
       xmlns:dcterms="http://purl.org/dc/terms"
       xmlns:iso19115="http://www.isotc211.org/iso19115/"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <xsl:output indent="yes" encoding="ISO-8859-1"/>
  ...
  <xsl:template match="/">
    <xsl:apply-templates select="rdf:RDF"/>
  </xsl:template>
  <xsl:template match="rdf:RDF">
    <xsl:if test="rdf:Description">
     <xsl:element name="iso19115:MD_Metadata">
      <xsl:element name="iso19115:_MD_Identification">
       <xsl:attribute name="xsi:type">iso19115:MD_DataIdentificationType
       </xsl:attribute>
        <xsl:element name="citation">
    <!-- CONVERSION OF TITLE ELEMENT: The title attribute is mandatory within
```

```
         CI_Citation entity. If there is no value for DC:TITLE, "Default Title"
         will be generated. -->
          <xsl:choose>
            <xsl:when test="./rdf:Description/dc:title">
              <xsl:element name="title">
                <xsl:value-of select="./rdf:Description/dc:title"/>
              </xsl:element>
            </xsl:when>
            <xsl:otherwise>
              <xsl:text>Default Title</xsl:text>
            </xsl:otherwise>
          </xsl:choose>
          ...
        </xsl:element> <!-- citation -->
        ...
    <!-- CONVERSION OF CREATOR ELEMENT: This element is optional in both standards.
      For each occurrence of DC:CREATOR, a new pointOfContact will be created. The
      text of DC:CREATOR will correspond to the CI_ResponsibleParty.organisationName
      attribute. -->
        <xsl:for-each select="./rdf:Description/dc:creator">
          <xsl:element name="pointOfContact">
            <xsl:element name="role">
              <xsl:element name="CI_RoleCode_CodeList">
                <xsl:text>originator</xsl:text>
              </xsl:element>
            </xsl:element>
            <xsl:element name="organisationName">
              <xsl:value-of select="."/>
            </xsl:element>
          </xsl:element>
        </xsl:for-each>
        ...
      </xsl:element>  <!-- iso19115:_MD_Identification -->
    </xsl:element> <!-- iso19115:MD_Metadata -->
   ...
   </xsl:if> <!-- of: <xsl:if test="rdf:Description"-->
  </xsl:template>
  ...
</xsl:stylesheet>
```

C

Applications

C.1 Revision of geographic metadata editors

Given the increasing importance of geographic metadata, numerous software packages (dedicated tools or plug-ins in GIS tools) have appeared during the last decade for the creation of metadata. Due to the extended use of CSDGM and the recency of ISO 19115, most of the metadata edition tools give only support to the CSDGM standard. A detailed revision of CSDGM-based tools can be found through the Web site of the FGDC [1]. However, nowadays most of them tend to migrate to ISO 19115 as soon as possible.

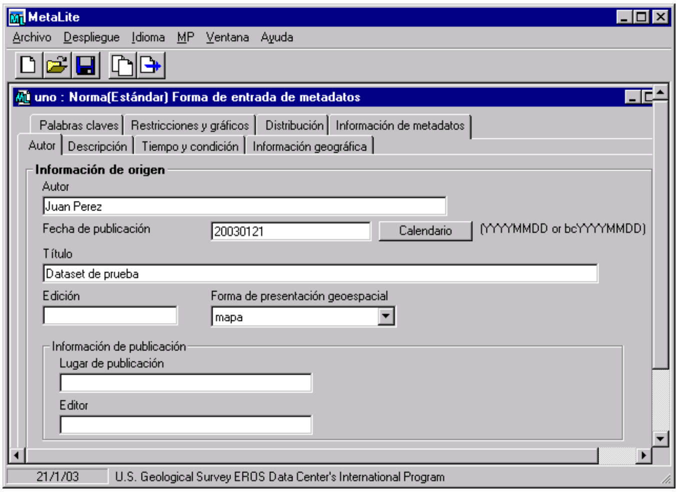

Fig. C.1. *MetaLite* tool

[1] Available at http://www.fgdc.gov/metadata/metatool.html.

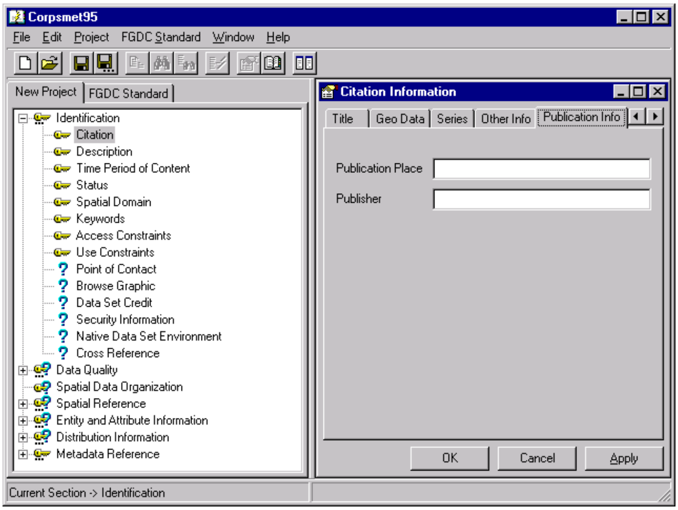

Fig. C.2. *CorpsMet95* tool

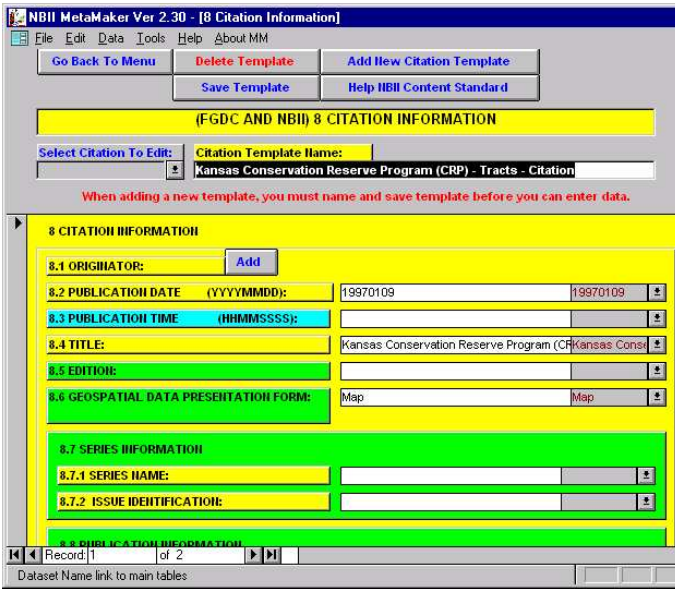

Fig. C.3. *MetaMaker* tool

Now, a reduced list of metadata edition tools will be briefly described. They have been selected by their relevance, extended use and their additional facilities for metadata creation. They are the following:

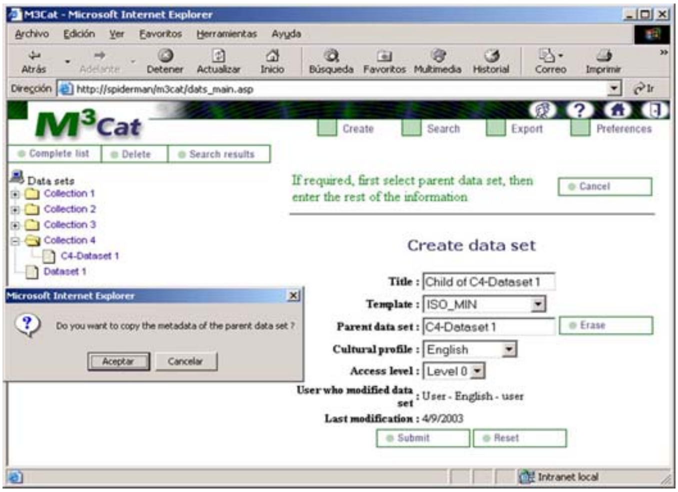

Fig. C.4. *M3Cat* tool

- One of the simplest but more extended tools is *MetaLite* [2] (see figure C.1), which has been developed by the FGDC and it is freely available. It only gives support for a minimum set of elements. It provides exchange in html, txt, sgml (xml) formats. This tool has been developed for Windows platforms (Visual basic) and stores metadata in an Access database. Additionally the application is delivered in 4 languages (es, en, fr, pt) and includes a small keywords dictionary in 4 languages.
- Another tool freely available is *Corpsmet95* (see figure C.2), which was developed by the U.S. Army Corps of Engineers [3]. It provides storage in text file (with extension *.met*) and works only in Windows platforms.
- *MetaMaker*[4] (see figure C.3) is also a freely available tool developed by the National Biological Information Infrastructure (NBII). It stores metadata in an Access database and can be operated in Windows platforms. Additionally it enables discovery of metadata records discovery by means of keyword searching.
- *MetaManager* [5] is another example that has been developed by a Canadian company called Compusult. This tool also provides software to publish metadata records as a Clearinghouse node conforming to the Z39.50 search and retrieval protocol. This software acts as a bridge between spatial databases (ESRI SDE, ...) and a Clearinghouse gateway.

[2] http://edcnts11.cr.usgs.gov/MetaLite/
[3] http://www.usace.army.mil/
[4] http://www.umesc.usgs.gov/metamaker/nbiimker.html
[5] http://www.metadatamanager.com/

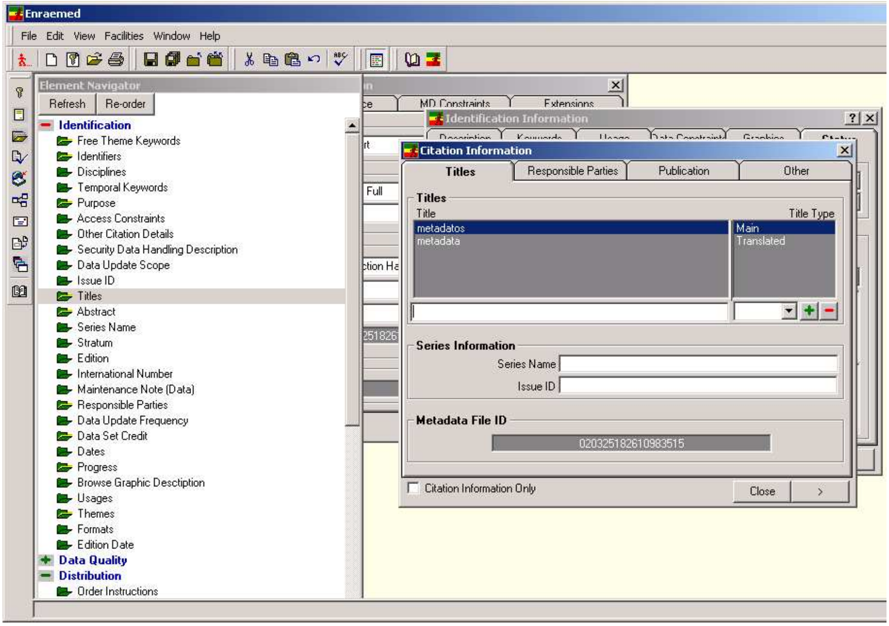

Fig. C.5. *Enraemed* tool

- *M3Cat* (see figure C.4) is a tool that has been developed a Canadian company called Intelec Geomatics Inc. [6]. This is a client-server Web application that stores metadata (according to different profiles and standards like ISO 19115 or CSDGM) in either an Access or an Oracle database. The most remarkable feature of this tool is that it gives support for hierarchical levels of metadata. However, at present this support only consists in a copy of metadata between parent and child datasets at the moment of child creation.
- *Enraemed* (see figure C.5) is a tool which was initially originated in 2000 by a project in Ethiopia, the Environmental Support Project carried out under Dutch-Ethiopian bi-lateral development cooperation. Later, the Global Spatial Data Infrastructure (GSDI), the FGDC and the United Nations Environment Programme agreed with Dutch-Ehtiopian governments for a technical exchange of this software. And nowadays, the software is being maintained and upgraded through the GSDI/FGDC. It is a client/server windows based application that supports ISO 19115 and CSDGM metadata. For metadata storage, SQL Server database is needed. Additionally, it gives support for metadata records discovery; it provides administration tools to create thesauri, and maps to help in the cataloguing process; and it is possible to configure different users of the application.

[6] http://www.intelec.ca/

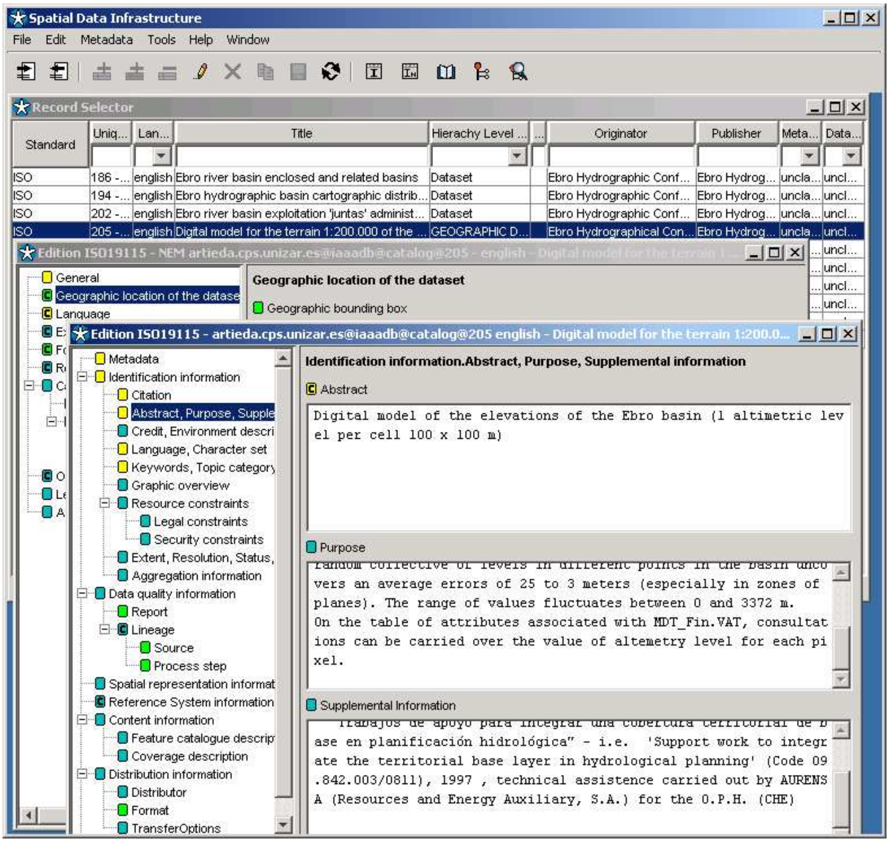

Fig. C.6. *CatMDEdit* tool

- *CatMDEdit* tool (see figure C.6) is an Open Source tool [7] which has been developed by TeiDE[8]. TeiDE is a Spanish consortium constituted by the R&D groups of the University of Zaragoza (Computer Science and Systems Engineering Dept.), the Jaume I University of Castellón (Dept. of Information Systems), and the Polytechnic University of Madrid (Topography and Cartography Dept.). CatMDEdit facilitates the documentation of resources, with special focus on the description of geographic information resources. Developed in Java, the main features of this tool are its multiplatform (Windows, Unix, Linux) and multilingual possibilities. Since the authors of this book, also members from TeIDE, have contributed to the development of this tool, further details of the tool can be found in section 5.3.

[7] http://catmdedit.sourceforge.net/
[8] http://teide.unizar.es/

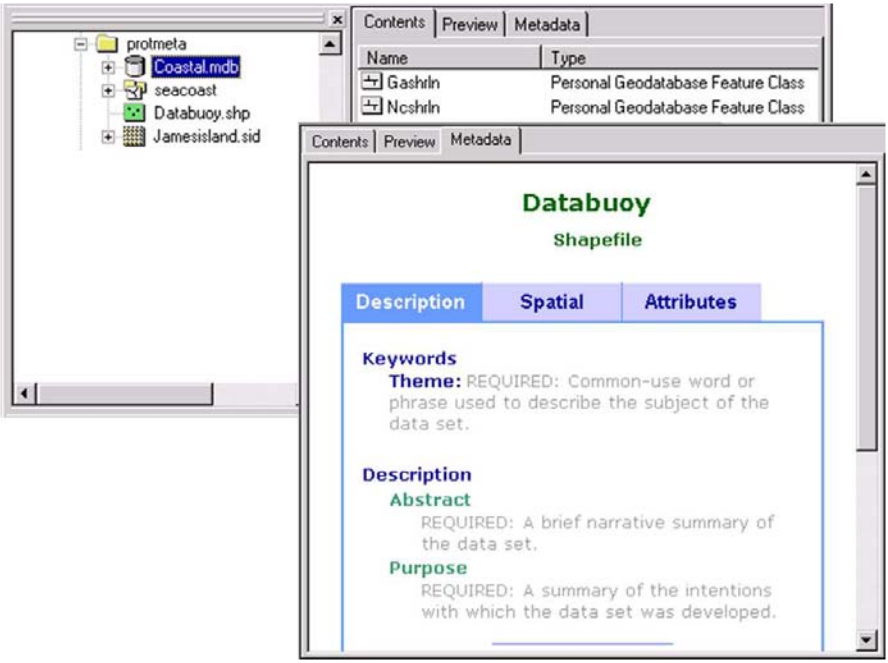

Fig. C.7. *ArcCatalog* tool

- And finally the *ArcCatalog* tool (see figure C.7), developed by ESRI[9], is perhaps one of the most widely used. Since the release of version 8.0 of Arc/Info, ArcCatalog enables metadata edition and automatic metadata generation for various types of sources (coverage, SDE, ...). It supports CSDGM (ESRI profile) and ISO 19115 (as much as possible). Metadata is stored usually in XML files together with dataset files, or inside the database for SDE One of the main features of ArcCatalog is the synchronization. Several metadata properties are automatically updated like the *spatial representation*, the *spatial reference system*, or the *entity and attribute information*. It also allows the creation of customized metadata editors (COM components) and presentation styles. And additionally the publishing of metadata records is possible by means of *ArcIMS*. The metadata generated by *ArcCatalog* can be integrated into *ArcIMS*.

C.2 Revision of thesaurus tools

The problem of creating appropriate content for thesauri has a great interest in the libraries field and other related disciplines. The fact to prove this interest

[9] http://www.esri.com

can be found in the increasing number of software packages that have appeared in last years for the construction of thesauri. For instance, the web site of Willpower Information [10] offers a detailed revision of more than 40 tools. Some tools are only available as a module of a complete information storage and retrieval system, but others also allow the possibility of working independently of any other software. And among these thesaurus creation tools, one may remark the following products:

- *BiblioTech*[11]. This is a multi-platform tool that forms part of BiblioTech PRO Integrated Library System and can be used to build an ANSI standard (Z39.19) thesaurus.
- *Lexico*[12]. This is a Java-based tool that can be accessed and/or manipulated over the Internet. It allows the definition of descriptive note fields that permit tracking of various details such as rationale for term selection, instructions for cataloging and retrieval, historical information, etc. This tool has been used by the U.S. Library of Congress to manage vocabularies and thesauri such as: the "Thesaurus for Graphic Materials", the "Global Legal Information Network Thesaurus", the "Legislative Indexing Vocabulary" and the "Symbols of American Libraries Listing".
- *MultiTes*[13]. This is a windows based tool that, among the main features, allows: support for an unlimited number of thesauri (both monolingual and multilingual); the automatic validation of conflicting relationships; up to 100 million terms per thesaurus and an unlimited number of hierarchies; and support for ANSI/NISO relationships plus user defined relationships and comment fields.
- *TermTree 2000*[14]. TermTree is a windows based tool that uses Access, SQL Server or Oracle for data storage. The tool verifies the validity of links as the thesaurus is created and automatically constructs all required reverse relationship links. Regarding import/export facilities, Term Tree 2000 can import/export TRIM thesauri[15] as well as a defined Term Tree 2000 tag format.
- *WebChoir*[16]. WebChoir is a family of client-server web applications that provide different utilities for thesaurus management. This family of tools supports multiple DBMS platforms. TermChoir is a hierarchical information organizing and searching tool that enables information professionals to create and search varieties of hierarchical subject categories, controlled vocabularies, and taxonomies based on either pre-defined standards or a

[10] http://www.willpower.demon.co.uk/thessoft.htm
[11] http://www.inmagic.com/
[12] http://www.pmei.com/lexico.html
[13] http://www.multites.com/
[14] http://www.termtree.com.au/
[15] Format used by the Towers Records Information Management system (http://www.towersoft.com/).
[16] http://www.webchoir.com

user-defined structure. LinkChoir is another tool that allows indexers to describe information sources using terminology organized in TermChoir. And SeekChoir is a retrieval system that enables users to browse thesaurus descriptors and their references (broader terms, related terms, synonyms, etc.), allowing the searcher many ways to investigate and employ related and synonymous topics and concepts while searching.
- *Synaptica* [17]. Synaptica is a client-server web application that can be installed locally on a client's intranet or extranet server. It has been developed with COM and Active Server Pages (ASP) technology and requires the installation of Internet Information Server (IIS), the web server of Microsoft. Regarding the storage, thesaurus data is stored in a SQL Server or Oracle database. The application supports the creation of electronic thesauri in compliance with ANSI/NISO Standard Z39.19-1993. The application also allows the exchange of thesauri in CSV (Comma-Separated Values) text format.

Another important aspect in thesaurus tools is the import/export capability. The main limitation with this respect is that the exchange format has not been standardized yet. The ISO norm for multilingual thesauri (ISO 5964) is currently undergoing review by ISO TC46/SC 9, and it is expected that among the new modifications it will include a standard exchange format for thesauri. It is believed that this format will be based on interoperable technologies like RDF/XML. In fact, some initiatives in this direction have already arisen:

- The ADL thesaurus Protocol (Janée et al., 2003) defines an XML and HTTP-based protocol for accessing thesauri. As a result of query operations, portions of the thesaurus are returned encoded in XML.
- The Language Independent Metadata Browsing of European Resources (LIMBER) project has published a Thesaurus Interchange Format in RDF (Matthews et al., 2002). Thesauri are used throughout the information retrieval world as a method of providing controlled vocabularies for indexing and querying. W3C is developing standards for the representation of ontologies to constrain the vocabularies of resource descriptions based on RDF. Such ontologies will allow distributed authoritative definition of vocabularies that support cross-referencing. And these ontology representations are planned to fulfill the role currently undertaken by thesauri. This work introduces an RDF representation of thesauri, which is proposed as a candidate thesaurus interchange format. This work also discusses whether it serves as a useful step on a migration path towards semantic web ontologies.
- The California Environmental Resources Evaluation System (CERES) and the NBII Biological Resources Division are collaborating in the

[17] http://www.synaptica.com/

CERES/NBII Thesaurus Partnership project [18] for the development of an Integrated Environmental Thesaurus and a Thesaurus Networking ToolSet for Metadata Development and Keyword Searching. One of the deliverables of this project is an RDF implementation of a representation of terms of a thesaurus.

- And finally, the "Semantic Web Activity: Advanced Development - Europe" (SWAD-Europe) project[19] is an EU-funded project (part of the IST-7 programme) also aiming at supporting the W3C's Semantic Web initiative in Europe. In particular, one of the activities of this project, SWAD-Europe Thesaurus Activity, has defined the Simple Knowledge Organization System (SKOS), a set of specifications and standards to support the use of knowledge organization systems (KOS) on the semantic web. And two of these specifications, SKOS Core and SKOS Mapping provide RDF vocabularies and models for describing thesaurus data.

Finally, it must be mentioned that, given that a thesaurus can be considered as an ontology specialized in organizing terminology (Gonzalo et al., 1998b), ontology editors could be another option for thesauri construction. (Denny, 2002) offers a detailed survey of ontology editors.

[18] http://ceres.ca.gov/thesaurus
[19] http://www.w3.org/2001/sw/Europe/

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