The RITMARE Starter Kit
Bottom-up Capacity Building for Geospatial Data Providers

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Keywords: Spatial Data Infrastructures, OGC Services, SWE, Marine Research.

Abstract: Capacity building by data providers is a fundamental task in the creation of a decentralized Spatial Data Infrastructure. This challenge has been tackled in the RITMARE Flagship Project by providing the Starter Kit, a comprehensive set of domain-oriented software components that exposes standard services for the management of geospatial information. We report on the characteristics of this toolkit, developed by the National Research Council of Italy (CNR), particularly with regard to the underlying service-oriented architecture and the novel semantics-aware methodology that is proposed for metadata editing.

1 INTRODUCTION

Spatial Data Infrastructures (SDIs) are frameworks for the collection and provisioning of geospatial data, metadata, networked services, and technologies. A number of standard services, such as the Web Map Service (WMS), allow for download and visualization of the resources that are discovered through a *Catalog Service for the Web* (CSW)[1] interface. In fact, differently from generalized search, where indexing and retrieval is driven by crawling (hyper)textual data on the Web, an SDI relies on specific metadata formats and access protocols to enable "discovery" of resources by users. It is essential for data providers to comply with such metadata formats (actually, they are often mandated to) and to expose appropriate services in order to mesh with existing data collections and to enable aggregation of their data by third-party applications (Gil et al., 2012; De Longueville, 2010).

Unfortunately, implementing a full-fledged infrastructure of this kind may feature a steep learning curve preventing researchers from properly managing the required technicalities. As a consequence, the exploitation of important datasets by the research community may be indefinitely confined to word-of-mouth. State-of-the-art SDI solutions may also make it difficult to seamlessly integrate novel categories of data sources, such as sensor data (Na and Priest,

2007). Moreover, the evolution of resource annotation paradigms, such as the change in perspective driven by Semantic Web technologies (Hitzler et al., 2009), makes existing infrastructures for geospatial data inadequate.

IREA-CNR tackled the challenge of providing an infrastructure to RITMARE, the Flagship Project for Italian marine research[2]. The variety of data formats and practices enforced by the distinct data providers, as well as the different degree of maturity of existing solutions, rule out any kind of "integration by standardization" approach. We favor instead a bottom-up methodology that may capitalize as possible on the practices established by individual data providers.

Among these, we first considered those with no existing infrastructure in order to abstract from protocol-level integration issues, focusing instead on the heterogeneity of data formats. This also allowed us to set a baseline for metadata which, in the European Union (EU), require standardization according to the INSPIRE Directive (European Commission, 2007), enforced in Italy by the *Repertorio Nazionale dei Dati Territoriali* (RNDT)[3]. The outcome is the RITMARE Starter Kit (SK), a capacity-building collection of software components packaged as a ready-to-use virtual appliance. The SK exposes standard data distribution services and establishes a CSW catalog service by the data providers.

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[1]Catalog Service for the Web:
http://www.opengeospatial.org/standards/cat

[2]RITMARE Flagship Project: http://www.ritmare.it/
[3]RNDT: http://www.rndt.gov.it

The catalog service that is exposed can either be used in isolation, for the discovery of resources made available by the specific data provider, or be exploited by a centralized catalog service integrating the distinct contributions to the project. The infrastructure's central node also empowers the SK with metadata editing capabilities that are based on a collection of semantics-aware, RDF data structures[4], as explained in (Fugazza et al., 2014).

Section 2 outlines the RITMARE infrastructure as a response to the project's heterogeneous audience and to the normative constraints for the management of geospatial data in Italy as well as in the EU; it also presents some related work that is relevant to the project. Section 3 details the characteristics of the SK with regard to the software provided and the services that are exposed to either end users and the centralized catalog. Section 4 describes the main contributon of the SK to the state-of-the-art, that is, the metadata editing service that allows for the creation of semantically-annotated metadata. Section 5 provides a preliminary evaluation of the approach that is presented. Finally, Section 6 draws conclusions and outlines future work.

2 THE SK IN THE RITMARE ARCHITECTURE

RITMARE is a Flagship Project by the Italian *Ministero dell'Istruzione, dell'Università e della Ricerca* which aims at fostering data sharing among the Italian data providers in the field of marine research. Subproject 7 is charged of building the SDI to be employed by the data providers themselves (public research bodies and inter-university consortia) and also by a variety of stakeholders (public administrations, private companies, and citizens).

A coarse-grained categorization of SDIs distinguishes between centralized and decentralized infrastructures, according to whether data and metadata is stored in a single repository or distributed among the distinct data providers. The RITMARE infrastructure will belong to the second kind, comprising:

- a set of peripheral nodes that expose standards-compliant metadata and services;

- a node that provides a centralized catalog, single point of access to the resources made available by the project as a whole.

The rationale for adopting a decentralized strategy is manifold. Firstly, by doing this, the implementation

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[4]Resource Description Framework:
http://www.w3.org/RDF/

strategies of existing infrastructures are not hampered by inclusion in the RITMARE SDI. Also, this approach allows data providers to retain full control over their data, metadata, and provisioning facilities. Finally, by federating the distinct data sources, no centralized management of sensitive data about users is required.

Data providers in RITMARE are scientists belonging to different communities (e.g., oceanography, ecosystems, biogeochemistry, geophysics, etc.). As a consequence, they envisage a varied corpus of heterogeneous data, metadata, workflows, and requirements. They also feature different degrees of maturity with regard to the solutions implemented for the provisioning of resources. This heterogeneity has been addressed by structuring the development activity in three incremental phases. The first one consists of empowering the data providers with standards-compliant services for the collection, annotation, and deployment of both geographic and sensor data, which is the purpose of the SK described in this work. The data sources that already expose standard services will be integrated in the second phase. Finally, the third phase will be the building of the centralized portal accessing the distinct peripheral nodes and exposing the metadata records as Linked Data.

A sketch of the interactions between end users, SK instances, and the centralized catalog is depicted in Figure 1 (directed arcs indicate which entity accesses which). In the picture, three distinct installations of the SK provide heterogeneous data (buoys data, bathymetries, and radar data) by exposing the services that are of interest to the specific category of data. Three categories of end users can access each of the peripheral nodes created by the SK both for the discovery of resources and for the actual download of data. These are data producers, stakeholders, and third-party applications within and outside the project. The centralized catalog of the RITMARE infrastructure aggregates metadata records from the distinct data sources so that the user can search for datasets made available by any of the harvested SK installations. Stored by this central node, RDF data structures support metadata creation by the peripheral nodes and enable advanced discovery functionalities.

2.1 Related framework

INSPIRE-compliant, XML-based metadata and OGC-based services (European Commission, 2008; IOC Task Force for Network Services, 2011a; Initial Operating Capability Task Force, 2012; IOC Task Force for Network Services, 2011b) set the framework for interoperability of geospatial data
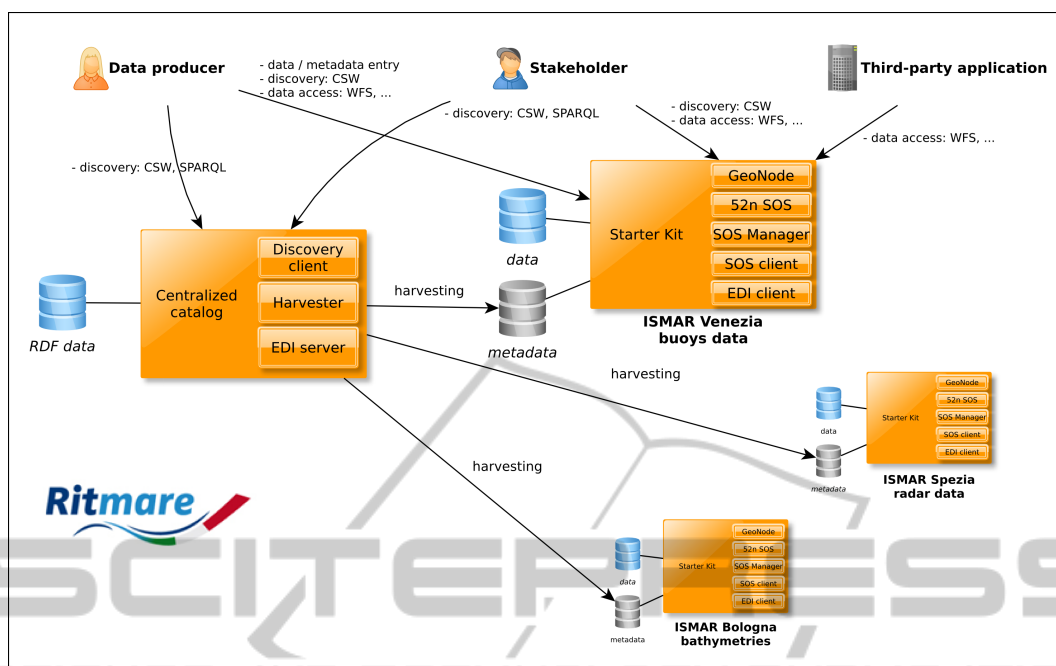
Figure 1: Instances of the Starter Kit in the RITMARE infrastructure.

among European countries. Whereas the framework provides "stubs" for bridging between mere protocol-level and real semantic interoperability (e.g., the multilingual codelists employed in metadata), it is unwieldy to accommodate these features in ISO 19115 format[5], the XML schema mandated by the Directive. This is the rationale for collecting, besides INSPIRE-compliant metadata, additional information that could ease implementation of more fine-grained search paradigms.

Another integration challenge is constituted by sensor networks, which represent an application field that is mature enough for inclusion in our infrastructure. The integration of sensor observations within SDIs is featuring many examples (Jiang et al., 2013; Hale and Hollister, 2009; Voigt et al., 2009; Collins et al., 2006). Also, many implementations are supporting the requirements for Sensor Web Enablement (SWE)[6][7][8]. However, the challenge of integrating sensor networks, particularly observations (the actual data produced by sensors), with traditional geographic data remains. In fact, Sensor Web development relies on specific standards and practices that

make it difficult to achieve this degree of integration.

3 THE RITMARE STARTER KIT

The main purpose of the SK is to enable researchers and research organizations to contribute their data and metadata to the RITMARE interoperable infrastructure. By means of the SK, data providers can upload and manage their data (both maps and observations), create the appropriate metadata for either datasets and sensors, and finally provide discovery, visualization, and access interfaces according to the standards. We focused on three main strategies:

- to simplify as much as possible the installation of the tools;

- to allow data providers to easily and directly manage, publish, and share their geospatial and observation datasets (without specific skills on SDIs);

- to foster reuse of the services provided by the SK in projects and initiatives outside RITMARE.

The SK is distributed as a ready-to-use virtual appliance which is packaged in the Open Virtualization

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[5]ISO 19115: http://www.iso.org/iso/catalogue
_detail.htm?csnumber=26020

[6]52°North: http://52north.org/communities/sensorweb/
index.html

[7]OOSTethys: https://code.google.com/p/oostethys/wiki/
JavaServerMain

[8]istSOS: http://istgeo.ist.supsi.ch/software/istsos/

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[9]WMS Tiling Clients Recommendation:
http://wiki.osgeo.org/wiki/WMS_Tiling_Client_Recommen-
dation

[10]Tile Map Service: http://wiki.osgeo.org/wiki/Tile
_Map_Service_Specification

Table 1: Services exposed by the Starter Kit.

SERVICE	VERSION	NOTES
OCG Web Map Service	1.1.1, 1.3.0	from GeoNode (GeoServer)
OGC Web Feature Service	1.0.0, 1.1.0, 2.0	from GeoNode (GeoServer)
OGC Web Coverage Service	1.0, 1.1	from GeoNode (GeoServer)
OGC Styled Layer Descriptor	1.0	from GeoNode (GeoServer)
OSGeo WMS Tiling Clients Recommendation[9]		from GeoNode (GeoWebCache)
OGC Web Map Tiling Service		from GeoNode (GeoWebCache)
OSGeo Tile Map Service[10]		a predecessor to WMTS, from GeoNode (GeoWebCache)
OGC Catalogue Services for the Web	2.0.2	from GeoNode (pycsw)
INSPIRE Discovery Services	3.0	from GeoNode (pycsw)
Search/Retrieve via URL (SRU) search protocol		from GeoNode (pycsw)
OGC SOS	1.0.0	from 52°North SOS
OGC Sensor Model Language (SensorML)	1.0.1	from 52°North SOS
OGC Observation and Measurement (O&M)	1.0.0	from 52°North SOS
OGC Geography Markup Language (GML)	3.1.1	from 52°North SOS

Format (OVF)[11]. The SK is based on the Ubuntu operating system and contains open-source software. In a nutshell, the SK is a web-based application and platform kickstarting a node in the SDI which is capable of managing geospatial and observation datasets and resources.

Besides the software that has been specifically created for the requirements of RITMARE, the SK also features a number of services provided by GeoNode and 52°North SOS, see Table 1. The SK is partly based on results of the CIGNo project (Bergamasco et al., 2011), a collaborative, federated system to share scientific and geographic data.

The software that has been customized or created for the SK allows to keep the data, metadata, and services tightly coupled. As an example, several metadata items are automatically extracted from datasets at upload-time and passed down to the metadata editor for insertion in the metadata record. The components that have been developed expressively for the SK are the following:

SOS Manager. Supports editing of SensorML for registering a new sensor and allows upload of observations as tabular data in a text file.

SOS Client. The interface allows to easily interact with an SOS service to retrieve, for each sensor, position, parameter list, offerings, and values.

EDI Client. The client-side component of the customizable, semantics-aware metadata editing service described in Section 4.

The management of geographic information is primarily mandated to GeoNode[12] (Benthall and Gill, 2010; Winslow, 2010), a widely acknowledged open-source software that is capable of dealing with maps, geographic layers, and also with geotagged documents. Besides geographic information, the SK is also capable of uploading, storing, and publishing sensor descriptions and the observations captured by the former. The main component that is bundled is the implementation by 52°North[13] of the Sensor Observation Service (SOS) specification and related facilities.

Since the services that are exposed by the two aforementioned components are differing in many aspects, the workflows for inserting in the SK, respectively, geographic and sensor data are kept separated. By doing this, all the extra features provided by the SOS implementation are retained. On the other hand, the coupling of the two categories of data sources emerges in the visualization features that are provided. In fact, integrated with the GeoNode Map Composer, the SOS Client executes requests and retrieves the data from an SOS endpoint, so that users can display on a GIS-like interface the position of sensors. The sensors can then be queried for the time series that are made available for one or more observed parameters: Data can either be displayed in classic tabular mode or be applied data visualization criteria. The SOS Client is a JavaScript library based on OpenLayers[14], ExtJS[15], and Flot[16].

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[11]Open Virtualization Format:
http://www.dmtf.org/standards/ovf

[12]GeoNode: http://geonode.org/

[13]52°North: http://52north.org/

[14]OpenLayers: http://openlayers.org/

[15]ExtJS: http://www.sencha.com/products/extjs/

[16]Flot: https://code.google.com/p/flot/

Listing 1: Code fragment from the RNDT template.

```
1   <element>
2     <label lang="it">Tipo di rappresentazione spaziale</label>
3     <label lang="en">Spatial representation type</label>
4     <isMandatory>forAll</isMandatory>
5     <isMultiple>true</isMultiple>
6     <hasRoot>
7       /gmd:MD_Metadata/gmd:identificationInfo/gmd:MD_DataIdentification
8     </hasRoot>
9     <produces>
10      <item>
11        <hasIndex>1</hasIndex>
12        <hasPath>/.../gmd:MD_SpatialRepresentationTypeCode</hasPath>
13        <isFixed>false</isFixed>
14        <hasDatatype>code</hasDatatype>
15        <hasValue>http://.../MD_SpatialRepresentationTypeCode/items</hasValue>
16      </item>
17      <item>
18        <hasIndex>2</hasIndex>
19        <hasPath>/.../gmd:MD_SpatialRepresentationTypeCode/@codeList</hasPath>
20        <isFixed>true</isFixed>
21        <hasDatatype>string</hasDatatype>
22        <hasValue>
23          http://.../gmxCodelists.xml#MD_SpatialRepresentationTypeCode
24        </hasValue>
25      </item>
26      <item>
27        <hasIndex>3</hasIndex>
28        <hasPath>
29          /.../gmd:MD_SpatialRepresentationTypeCode/@codeListValue
30        </hasPath>
31        <isFixed>true</isFixed>
32        <hasDatatype>ref</hasDatatype>
33        <hasValue>/.../gmd:MD_SpatialRepresentationTypeCode</hasValue>
34      </item>
33    </produces>
34    ...
35  </element>
```

4 METADATA CREATION IN THE SK

One of the most important components in the SK is EDI, a customizable, template-driven metadata editor that has been developed within RITMARE by leveraging a variety of complementary techniques. The rationale for this is to employ the more appropriate technology for each of the distinct phases in the workflow for metadata creation. For the time being, we support the editing of RNDT (i.e., INSPIRE) and SensorML metadata. However, the data model underlying template creation, encoded as an XML Schema[17], should be expressive enough to support most of the metadata formats in the SDI domain. As an example, support for sensor metadata in the alternative *FL (Starfish Fungus Language) format (Simonis and Malewski,

2011) is under testing.

The only input required by EDI to assist composition of metadata records in a given XML format is an appropriate template. The template language introduces the primitives that are necessary for the definition of metadata *elements*, intended as high-level abstraction of the information that can be either provided by the user or pre-computed by the application itself (such as the geographic boundary, the so-called "bounding box", that can be automatically computed at data upload-time). Each *element* defines one or more *items* that correspond to the individual XML nodes (elements and attributes) that are populated in the metadata record. Listing 1 shows a fragment of the RNDT template governing the creation of metadata in the ISO 19115 XML format, the standard underlying INSPIRE metadata.

The essential information defining an *element* is the language-dependent textual representation to be

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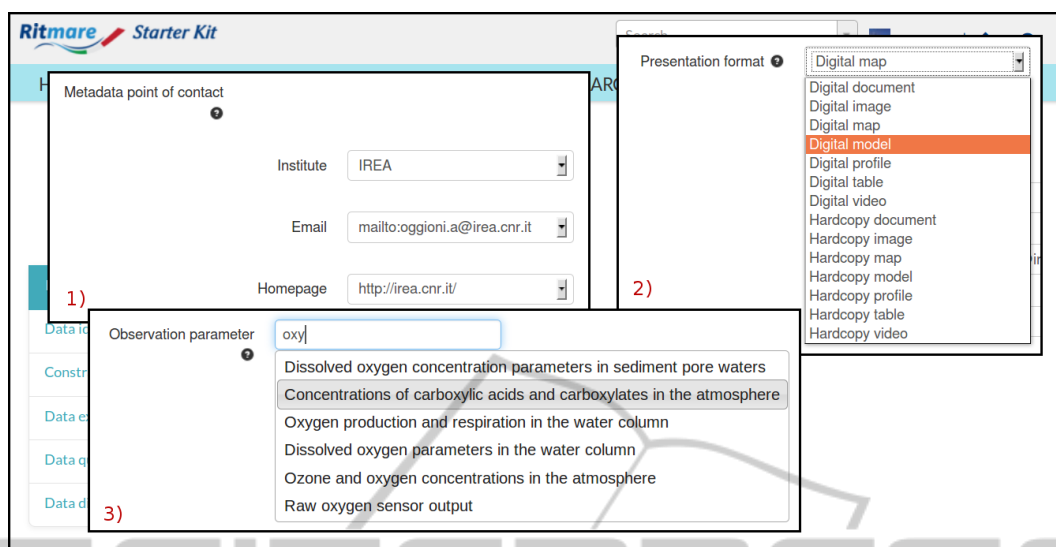
[17]XML Schema: http://www.w3.org/XML/Schema

Figure 2: Portion of the EDI metadata editing interface.

displayed in the interface (lines 2 and 3), the compulsoriness of the metadata item (one of "forAll", "forData", "forServices", "forSensors", and "NA" on line 4), its multiplicity (line 5), and the XPath defining the position where multiple instances of the metadata field shall be rooted (lines 6-8). Instead, the distinct *items* associated with the element define the specific XML nodes that shall be generated. In the HTML form interface generated by EDI, the user is presented the form fields that correspond to *items* whose parameter *isFixed* is set to "false" (as on line 13). For these, parameter *hasDatatype* specifies the data type of the specific metadata element. In the listing, the first *item* defining element "Spatial representation type" is of type "code", meaning that the possible values shall be taken from a controlled vocabulary: In this case, parameter *hasValue* specifies the unique identifier (the URI) that is necessary for retrieving the allowed values for the field.

EDI processes the template through an XSLT stylesheet, the most suitable means for processing XML data, and generates the actual HTML form that is displayed in the user's browser. Still, this interface is a dumb form that only distinguishes between input fields, text areas, dropdown lists, etc. but whose input fields and text areas have no predefined values, whose dropdown lists have no options (the values selectable by the user), etc. In fact, it is up to the JavaScript component of EDI to dynamically load these contents: For doing this, the JavaScript code accesses codelists and controlled vocabularies stored in the RDF triple store on the server-side, as described in (Fugazza et al., 2014). These categorizations of terms also provide all the accessory information that is required for cre-

ating the *items* that are either fixed or dependent on the user's choices (the items whose parameter *isFixed* is set to "true").

Let aside relieving the user from the burden of providing these additional data, recourse to RDF data structures allows the SK to annotate metadata with unique identifiers (e.g., the URI corresponding to the INSPIRE Theme the user may select) that will be used later on, when metadata is harvested by the central catalog collecting the contributions of the distinct peripheral nodes of the RITMARE infrastructure. This information may not be exposed (or leveraged on in discovery) by the individual catalogs of peripheral nodes but constitutes the fundamental step for providing advanced query functionalities by the overall infrastructure. Also, among the RDF data that EDI accesses for initializing the form fields is information related to the institution hosting the peripheral node of the infrastructure. This allows the client application to suggest values for a number of metadata fields.

Specifically, the semantics-aware characterization of data items allows the interface to provide three distinct functionalities:

- the automatic provision of values for metadata fields whose content depends on the choices that have been made for other metadata fields;

- the generation of dropdown lists on the basis of the mandated codelists, translated into the specific language that is chosen for the metadata;

- the autocompletion of metadata fields whose values shall be taken from controlled vocabularies that are too large for rendering as a dropdown list.

Figure 2 shows a portion of the HTML form that

is generated by EDI after the execution of both the XSLT transformation and the JavaScript code mentioned above. In particular, the image focuses on three distinct fields (the metadata point of contact, the presentation format, and the observation parameter a given dataset is related to) to exemplify the three distinct means we evisaged for the assisted editing of metadata.

In box 1, the authentication information that has been provided by the user allows the interface to suggest the distinct metadata items that are required for specifying a point of contact (the institution the person is working by, the website associated with the former, and the person's email address). Box 2 allows for the specification of the presentation format by selecting among the codes that have been defined by the INSPIRE Directive. The list (as well as field names, interface menus, and buttons) is populated on the basis of the language that is chosen for metadata editing. Finally, box 3 shows the input field that is used for providing the observation parameter (a *keyword* in the ISO metadata lexicon): Autocompletion capabilities provide the user with the range of observation parameters defined by SeaDataNet[18], an outstanding European marine project.

Once fields have been filled in, the EDI Client posts the metadata to the EDI service hosted by the central node of the RITMARE infrastructure. This metadata is used for accomplishing two distinct activities. On the one hand, to create a metadata record that has all the expressiveness elicited by the interface (essentially, an XML file very similar to the original template, whose fields are filled in with the actual values entered by the user). Secondly, the actual XML corresponding to the metadata format the template was written for is produced (for the time being, either RNDT or SensorML). Both these files are sent back to the local SK installation.

5 DISCUSSION

In the current phase of the project, when the centralized geoportal is still work in progress, an overall evaluation of the proposed solution is not easy. However, we are already collecting feedback on the capacity building of data providers envisaged in the first phase of the project (see Section 2), that is, we can report on the efficacy of our Starter Kit. In particular, we can evaluate the features that we are providing for the assisted editing of metadata.

With respect to these, recourse to the RDF data

structures allows to dramatically reduce the number of the data items to be actually provided by the user. As an example, the RNDT specification is featuring 34 mandatory metadata items, too high a number for an accurate editing of metadata records. Moreover, some of these, such as the 4 distinct contact points to be provided, are composite items that require more than one value to be entered by the user. Instead, by combining i) the automatic assignment of metadata items, ii) the provision of default values extracted from the dataset itself, and iii) the exploitation of the RDF information described in (Fugazza et al., 2014), the number of required values can be narrowed down to 10.

Particularly, by referring to the project structure, the editing interface is capable of providing data items that are otherwise tedious to provide or error-prone. Also, autocompleting keywords from the selected thesauri configures a win-win situation where the user is relieved of the burden of writing keywords in their entirety and the application is capable of associating unique identifiers with the keywords that are provided. These advanced editing capabilities can be applied to generic metadata schemata encoded as XML. In fact, we currently support the editing of sensor metadata in the SensorML format with the same autocompletion facilities of RNDT metadata.

An important requirement that has been underestimated in the analisys phase is the need for appropriate updating and monitoring facilities. In fact, once individual nodes are up and running, it is extremely difficult to update remote components without hampering operativeness of the node. Another lesson learnt is related to dependencies on third-party software that require thorough testing before upgrading the version provided in the SK. Specifically, when migrating from version 3.2 to version 4.0 of the 52°North SOS implementation, much work was required for updating the interfaces between this software and the rest of the SK.

6 CONCLUSIONS

This paper described the approach to capacity building for geospatial data providers that has been adopted in project RITMARE. A variety of open-source software has been bundled in the Starter Kit, a virtual appliance capable of establishing a fully-functional SDI node out-of-the-box. A comprehensive set of standards-compliant services allows to easily manage both geographic data and sensor observations; the SK also provides a uniform mechanism for metadata creation. Set-up of the nodes in the RITMARE SDI that

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[18]SeaDataNet: http://www.seadatanet.org/

are based on the SK is ongoing.

The overall infrastructure contributes to the enactment of the SK installations by providing services for the management of metadata that annotate resources semantically. These annotations are then employed by the central node for a twofold purpose: i) to implement novel techniques for the organization of widgets in the geoportal's main interface and ii) to enable inter-disciplinary discovery of the geospatial resources that are aggregated.

Future steps will involve the integration into the infrastructure of the data providers that already expose suitable services. Some existing tools, such as the GI-cat brokering application[19], already allows access to heterogeneous data sources. This is interoperability at protocol-level while, in our scenario, the challenge is to allow the research communities to interoperate at a higher level. As an example, the expressiveness of individual metadata items should be augmented through lookup in controlled vocabularies or semantic indexing methodologies.

RITMARE will provide a uniform point of access to all the data sources involved in the project (either SK instances or not); the user interface will flexibly adapt to the interests, requirements, practices, and devices of individual researchers in the project.

ACKNOWLEDGEMENTS

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[19]GI-cat: http://essi-lab.eu/do/view/GIcat