Web Processing Services to Describe Provenance and Geospatial Modelling

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***Abstract*— There are still some gaps regarding the complete geospatial provenance description. These gaps prevent the use of provenance information for replication and reproducibility task. In addition, the lack of automated tools for capturing the provenance is an obstacle to a widely generation of provenance information. In this sense, we present a tool that captures and represents provenance information based on the combined use of Web Processing Service (WPS) standard and the ISO 19115 lineage model. The tool, developed in the frame of the MiraMon GIS & RS software, shows a graphical visualization of provenance and allow users to edit provenance information by adding or deleting process steps or sources to a geospatial workflow. The automatic capture of lineage information is a step forward in the development of a model constructor tool. It will allow reproducing previous process workflows and applying them to other similar situations.**

Keywords- Provenance; WPS; Modelling

I. INTRODUCTION

Buneman [1] defines provenance information as the description of data origins and the processes by which a dataset is created. This includes also the description of the algorithms used, the processing steps, the inputs and outputs, the computing environment where the process runs, the organization/person responsible for the product, etc [2][3]. In the context of scientific models, data provenance records the workflow processing steps and their inputs/outputs that contribute to the production of the final data products [4].

The scientific community is interested in provenance information because it provides important information to determine the fit for purpose and the reliability of a product. In the geospatial domain data provenance plays a significant role in data quality and usability assessment [5], among others qualities. Moreover, if data provenance information is complete and points to real data and metadata, it can be used as a source for a workflow replication (with other inputs) or for data replication (reproducibility purposes) [2].

As a result of web-technology improvements that have reduced the data volume, computing steps, and resources required by the end-user, geospatial data and geoprocessing tools are available as services [6]. More recently, *Model as a Service* (MaaS) approach has been defined [7][8]. In this paradigm, where the origin of data has a high level of heterogeneity, several authors [9][10] see that provenance information is even more important for inspecting and verifying quality, usability and reliability of data.

Although that the importance of provenance in the geospatial community is documented, its complete description in geospatial metadata is still scarce [11]. Usually, most of the geodata come with some provenance information but in many cases only as a simple textual description, thus having a negative impact on its automated usage [12]. According to *Di* et al. [5], there are two main obstacles that generate this situation: the lack of standards that fully describe provenance information models ensuring reproducibility, and the lack of automated tools for capturing the provenance information.

To exchange and share geospatial data provenance in a distributed information environment, an interoperable model for provenance is needed [13]. The geospatial community has traditionally used the ISO 19115 [14] and 19115-2 standards to encode metadata and provenance [15]. However, there are still some gaps in the ISO models, such as the concrete model initialization, its basic assumptions and parameters values. These deficiencies prevent the complete description of provenance and blocks it use in workflow replication and data reproduction tasks.

Besides representation, provenance applications also need to ensure provenance capture, management and retrieval [16]. In addition, automatic tools that capture and store provenance as a part of metadata information are needed. Most of the work has focused on analysing and capturing provenance information that was created during execution, rather than on metadata generated before execution [17]. However, tools that document provenance before and after the execution are needed too.

In this regard, we have implemented a provenance engine tool that automatically captures and represents provenance information based on the combined use of Web Processing Service (WPS) standard and ISO 19115 lineage model. The tool, developed in the framework of the MiraMon Geographic Information System (GIS) and Remote Sensing (RS) [18], presents a graphical visualization of provenance and allow users to edit provenance information of a geospatial workflow before and after the execution. This automatic acquisition of geospatial provenance represents a step forward in the development of

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a model constructor tool in the context of MiraMon software.

This paper is structured as follows. Section II introduces related work, then sections II and III present the use of WPS to capture provenance and the developed tool. Following section IV introduces the efforts done in generating geospatial models from the captured provenance information. Finally, the conclusions are presented in the last section.

II. Related Work

When selecting a standard for describing provenance in the geospatial domain, some requirements should be taken into account [3]. For Di et al. [5] ISO 19115 and ISO 19115-2 templates are enough to record the complete geospatial lineage. Alternatively, He et al. [14] combines ISO 19115 with W3C PROV [19] to better describe provenance. Others, such as Lopez-Pellicer et al. [20] propose to adapt and extend the W3C PROV model to geospatial community requirements.

Beyond the models used to capture and store provenance, an effective visualization of provenance is also necessary to understand and evaluate data [21]. There are different types of visualization proposals [22], namely:

- Provenance as node-links: data is represented as points and processes as lines. [23][24].
- Provenance as a radial plots: Brings a visual focus to the relationships rather than the relative spatial locations [25].
- Tree diagrams: This technique displays a tree-form diagram starting from the data that is being analysed. Most provenance data have hierarchical properties or attributes [26][27]. Thus we found this type a suitable one to describe provenance.

When generating a geospatial model from concrete executions, a generalization process have to be carried out to standardise and reference the common processing functions. Yue et al. [28] use three levels of encapsulation to reduce the difficulty of sharing and use geo-analysis models in the web. Otherwise, Müller [29] proposes a hierarchical approach to process definitions with different abstraction levels. WPS process profiles [30] are also useful to determine which information from the concrete execution needs to be added to the model to ensure it reusability. An Application Profile is essentially the same as the ProcessDescription document obtained in response to a *DescribeProcess* request [31] (Fig. 1). This approach is in line with our approach of using the WPS standard to capture provenance, consequently we will use *DescribeProcess* documents to generalise models.

III. WPS to capture geospatial provenance

A. DescribeProcess documents to capture Provenance

The Web Processing Service (WPS) Interface provides rules for standardizing inputs and outputs (requests and responses) for geospatial processing services [32]. WPS instances are exposed via HTTP-GET, HTTP-POST and SOAP [33] Internet protocols. The potential of geoprocessing applications supported by the WPS allows to apply it in a wide range of fields [34]. Its main properties are: remotely execution, chain of several processes and standardized encodings for data and metadata. WPS is applied in many different fields and sectors that need geoprocessing applications; in particular it is successfully implemented for environmental models [35][36] and in combination to other standards: WPS+OpenMI [37], WPS+WCS [38], WPS+WFS [39]. WPS has three main operations: *getCapabilities, describeProcess and Execute.*

The *describeProcess* is the operation that allow a client to request and receive back detailed information about the processes that can be run on the service instance, including the inputs required, the allowable formats, and the outputs that can be produced [32]. The *describeProcess response* documents use the eXtensible Markup Language (XML). The information described in the WPS describeProcess documents(Fig 1) is the following:

- Process Description: A description of the process and an Identifier.
- Inputs: The input description, the dataType (*ComplexData*, *BoundingBox*, *LiteralData)*, the MIME type, an identifier and the name.
- Outputs: The output description, the dataType (*ComplexData*, *BoundingBox*, *LiteralData)*, the MIME type, an identifier and the name.

Considering that provenance information is the description of processes and sources, *describeProcess* documents could also be used to document provenance information. In addition, *describeProcess* operation can be requested in a local environment. This provides a magnificent opportunity to capture provenance automatically in a GIS local instance. In our case, we have used the *describeProcess* documents to describe all the MiraMon Applications (App), and capture its provenance information when executed. This permits the system to reference sources as a complex data, bounding box or capture the values of the *LiteralData* type.

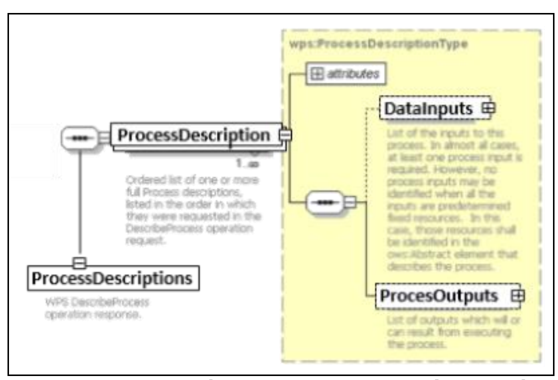

Figure 1. WPS DescribeProcess response UML diagram. The DescribeProcess schema is composed by a processDescription tag that includes a list of DataInputs and ProcessOutputs.

WPS is enough well known for the geospatial community, and this allows to jump the interoperability wall. More detail about the use WPS *describeProcess* documents in the context of MiraMon GIS & RS software are provided in Section III.

B. *Combining WPS and ISO to describe provenance*

As mentioned, we have detected some limitations in the ISO 19115 models that prevents the reproducibility of geospatial data using provenance information. In order to overcome this issue we propose the combination of the ISO provenance schemas (LI_Lineage and LE_ProcesStep) with *WPS describeProcess* documents (Fig. 2) presented in the previous section. Combining these two models allows to describe provenance as an ordered list of processes with ISO, including a WPS description of sources and outputs of each process step.

The ISO 19115 and 19115-2 can be described using the *eXtensible Markup Language (*XML). In fact, the ISO 19115-3 provides the XML implementation schema for ISO 19115 and 19115-2 and may be used to describe, validate, and exchange geospatial metadata. The lineage models of ISO (LI_Lineage and LE_ProcessStep) allow to describe the provenance information in three different ways:

- A list of process steps and a list of sources separately.
- A list of all the sources used and then add the description of all the processes as a child.
- A list of all the process steps that use some sources.

Describing provenance with a list of processes that use some sources provides the better way to report a complete record of provenance [12], because it follows the workflow execution. Thus, we use ISO in this way because permits the full description of provenance of a workflow as an ordered succession of different process steps**.** ISO model describes for each intermediate step the sources used and the outputs generated.

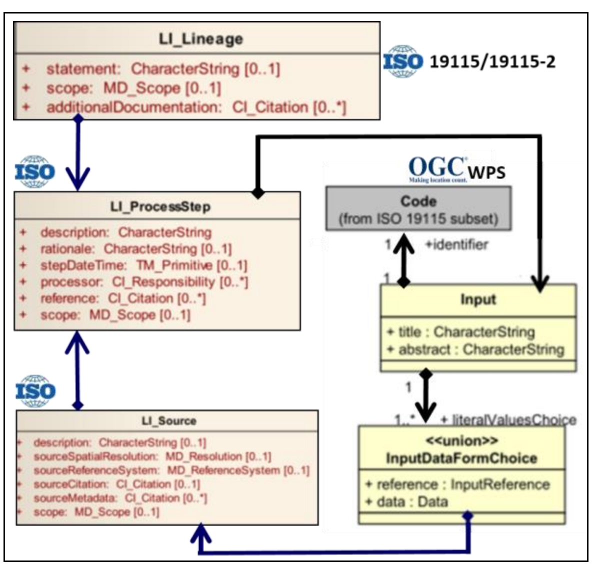

Figure 2. ISO 19115 provenance model combined with WPS model.

However, when describing sources, there is no place to indicate the data type or the value used (for literal data). In this context, to improve the description of the sources and the outputs of each step we introduce the use the *WPS DescribeProcess* to capture, among others characteristics, the data type and the literal data values. The sources and outputs used in each process step of the WPS are connected via identifiers to the ISO schemas.

The combination of ISO provenance schemas with WPS permits the automatic description of the algorithms used, the processing steps, the execution dates, the data type, the units (when necessary) and data values or data location.

The detected gap (no place to define the data type or the value used for literal data) has been introduced as a request for the revision of ISO 19115-2 and we are working with the editors to extend the standard to include this information.

IV. PROVENANCE ENGINE TOOL

A. *Provenance capturation in the context of GEMM*

MiraMon is a Geographic Information System (GIS) and Remote Sensing (RS) software [18]. The main characteristic of MiraMon software is that metadata are carefully managed and completely integrated with the dataset, which allows, at every processing step, to program automatic decisions based on quality information from the previous steps in the process chain [40]. MiraMon incorporates a Metadata Manager (GeMM) to ensure maximum documentation of layers. GeMM allows generating, editing and saving metadata, including the description of the data model and the relations with databases for several hierarchical levels (dataset to several dataset series). The metadata information is stored in REL format documents, which are the native format of MiraMon to document and store metadata information. These files store metadata about identification, extent, related databases, responsible party, technical specification and quality information [41][42]. In addition, as a part of quality information, there is also place for documenting provenance information. REL documents conform to INSPIRE ISO 19115 and FGDC standards and. moreover, metadata can be exported to HTML or XML (ISO 19139) files. Unlike others purely documentary applications, GeMM maintains the dependencies and consistency by checking coherence between metadata and datasets.

MiraMon software has more than 90 applications. In order to capture provenance information automatically, the main task has been the generation, for each App, of a *DescribeProcess response* template that describes the process and its allowed input and output data types. In addition, we use the optional tag *ows:metatada* to define the exact syntax and order of the parameters.

The provenance engine, using the WPS *DescribeProcess* templates, captures provenance of each process carried out and stores it in the metadata files as a part of the quality information of the dataset.

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The provenance engine is a piece of code that is shared by the visual interface of the GeMM and the MiraMon Apps. It is encoded as a library of C functions that can be linked to each module. Each App uses these functions to read metadata of the source datasets, load it, integrate it, and add the current App process step in the provenance information of the resulting dataset.

The provenance engine writing function can select between two alternatives: a) include all lineage details: complete sequence and description of process steps and previous data sources; or b) write only the last process step and link to the metadata sources. To save space, the generic purpose of each process step and its parameters is not stored. Instead, only identifiers are recorded. The reading function supports the two alternatives described before, being able to read the provenance information by following the links to previous sources recursively if needed. The graphical interface of GeMM requires a more elaborated set of functions to enrich the presentation of provenance information extracted from a *DescribeProcess* response template.

This allows the GeMM to capture, concurrently to an App execution, provenance information using the *DescribeProcess response* templates of each App (Fig. 3).

The system captures the exact parameters and values involved in an execution (that can be numbers, text strings, or bounding box data) and references to datasets or to data services. The system updates metadata information at every intermediate step maintaining the dependencies between the datasets and metadata files during all the workflow execution. The tool keeps track of the dependencies to source datasets and can browse to their metadata too.

B. Provenance editing and visualization

In complex environments, scientists rely on visualization tools to help them understand large amounts of data that are generated from experiments [24].

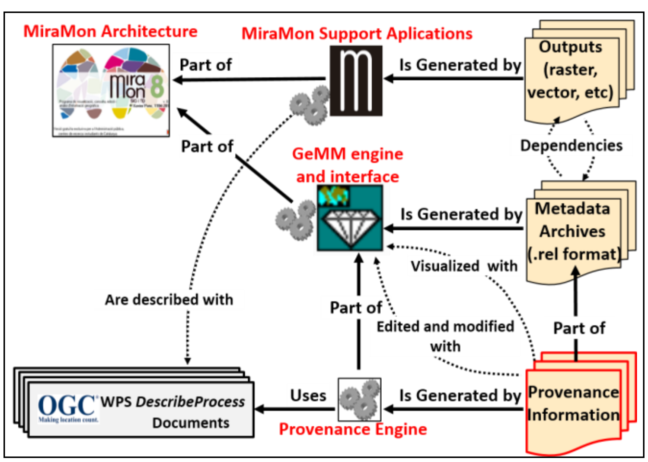

Figure 3. Provenance Engine uses WPS *DescribeProcess* documents to extract provenance information and then the GeMM interface allows users to edit and modify provenance.

According to Steele et al. [43], there are two categories of data visualization *Exploratory*, designed to support researcher who has not certain what is in it; and *Explanatory*, when a researcher is trying to explain the data to someone else. This differentiation remits also to the contraposition of the "*data user needs*" in front of "*data producer needs*", where the user needs more exploratory visualization ways, while producers more explanatory. The graphical interface of our provenance engine fits for both, exploratory and explanatory data visualization approaches.

The provenance engine presented in this paper helps data users to navigate and interpret provenance. The tool represents provenance information as a succession of processes. Each process has an indented list of all parameters used and outputs generated. At the same time, some parameters of the workflow are derived by previous processes (child process), which have, in a deeper level, its own indented list of parameters used, and so on. Thereby, the structure of the provenance schema is progressively increasing its profundity reminding a hierarchical indented form (Fig. 4). From our point of view, this tree-like provenance structure is a suitable way to visualise the provenance information because can easily represent the flow of a specific chain of processes.

The graphical interface of GeMM allows also editing provenance information by adding or deleting child processes or child sources to a geospatial workflow. Moreover, the algorithm description, the processing steps carried out, the execution dates, the responsibility of the product and the processes order can be edited and adapted to each scenario if necessary. This allows data producers to complete the provenance description automatically captured during the process or workflow execution.

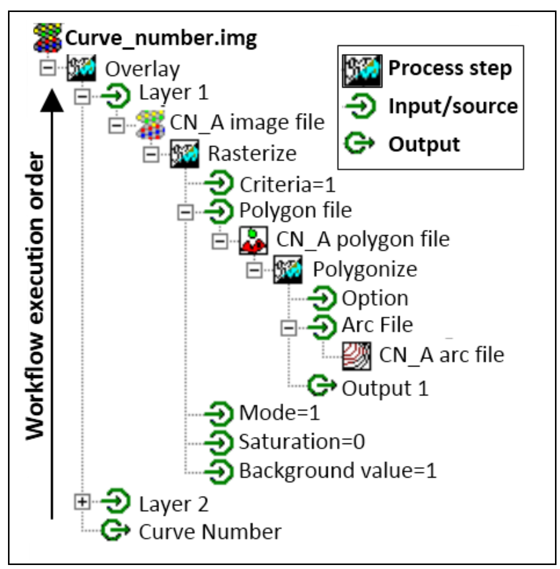

Figure 4. Tree-like provenance workflow representation in GeMM. The example shows processes and sources used in the layer (Curve_Number.img) generation.

V. GEOSPATIAL MODELLING

The automatic acquisition of geospatial provenance provides the complete recipe of the geospatial data generated. This supposes an opportunity to develop a model constructor tool in the MiraMon architecture. A model constructor allows the reproduction of previous chains of processes in different scenarios and applying them to similar situations using the provenance captured from previous executions.

Models, as a general representation of a system, are used to understand and simulate a geospatial phenomenon. Thus, a model have to provide enough information to enable the model users to apply it in different scenarios. As pointed in section II there are different approaches in order to generalize specific workflows. In our case, to document models we use the same WPS *DescribeProcess* templates generated to capture provenance. The WPS templates provide the necessary information of each App (process description, process syntax, algorithm location and parameters data type) to allow users to understand each individual process that conforms the model.

The provenance tool (presented in Section III) provides the specific order of the process chain and allows browsing the data inputs of each intermediate step, if necessary.

Finally, all captured information can be automatically exported as a batch file. The generated batch files points to processes and sources used to run workflows. Thus, this allows users to easily reproduce a workflow, or replicate it with different conditions (scope, data, parameters, algorithm options, etc). In addition, the collection of MS-DOS command lines permits automatize executions and ease the use of loops to process large volumes of data.

VI. CONCLUSIONS

Geospatial provenance facilitates geospatial data evaluation for reuse, and brings us closer to the replication of process chains and geospatial modelling. We have detected that there still some gaps regarding to the complete geospatial provenance description, affecting the provenance usefulness. Some gaps detected in the ISO 19115 lineage model has been introduced as a request for the revision of ISO 19115-2.

In this paper, we have shown that the combination of WPS *DescribeProcess* documents with ISO model provides a more complete provenance description. As a proof of concept, we have presented a provenance engine in the framework of MiraMon GIS and Remote Sensing software. The tool allows automatically capturing provenance information and its manually edition if needed. In addition, the automatic description of provenance information is a step forward in the development of a model constructor tool in the context of MiraMon software.

The near future efforts should point to enhance the process chaining and model generation in a distributed environment using provenance information.

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