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An RM-ODP Enterprise View for Spatial Data Infrastructures

Rubén Béjar[a], Miguel Á. Latre, Javier Nogueras-Iso, Pedro R. Muro-Medrano, F. Javier Zarazaga-Soria

Computer Science and Systems Engineering Department, Universidad de Zaragoza, c/María de Luna 1, 50018, Zaragoza, Spain

[a]*rbejar@unizar.es*

Abstract

Spatial Data Infrastructures (SDIs) are large, open, distributed and standards-based information systems which intend to facilitate and promote the use of spatial data and spatial services on the Internet. Spatial data describe information tied with locations on Earth, while spatial services allow to manipulate spatial data following a Service Oriented Architecture. This paper proposes to model SDIs as federations of autonomous communities following the enterprise language of the ITU-T and ISO/IEC 'Reference Model of Open Distributed Processing' (RM-ODP), and the recently approved 'Use of UML for ODP Systems Specifications' (UML4ODP). The enterprise language of the RM-ODP provides a conceptual foundation to address several aspects of SDIs not previously considered from a systems architecture point of view. The use of UML4ODP provides a modelling language to facilitate the exchange of knowledge about SDI, and it is an opportunity to try this recent standard for a class of large and complex systems.

Keywords: RM-ODP, Enterprise Architecture, Service Oriented Architecture, Spatial Data Infrastructure, UML, Distributed System

1. Introduction

The importance of spatial data to support decision-making and management has been cited as critical in important United Nations (UN) events such as the 1992 Rio Summit, the special session of the UN General Assembly to

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appraise the implementation of the Agenda 21 in 1997, or the World Summit on Sustainable Development in Johannesburg in 2003 [1]. Spatial, or geographic, data describe information tied to some locations on Earth's surface or to zones adjacent to it.

In the last decade of the 20th century, the use of spatial data was limited due to its high prices and the use of closed and monolithic systems. To improve that situation, the development of Spatial Data Infrastructures (SDIs) was proposed as a means to facilitate the discovery, access and use of spatial information. According to the 'SDI cookbook', 'the term 'Spatial Data Infrastructure' (SDI) is often used to denote the relevant base collection of technologies, policies and institutional arrangements that facilitate the availability of and access to spatial data' [1, p. 8]. Other relevant definitions for the term SDI are cited in [2], but in general these definitions share common objectives and similar components, which have been similarly categorized by different authors: from the people, policies and agreements, standards and technologies proposed in [3] to the framework composed of data, people, institutional frameworks, technology and standards in [4, p. 22-23]. SDIs are complex systems, and under this point of view have been considered Systems of Systems [5] and Complex Adaptive Systems [6]. Nowadays, SDIs are being developed in many countries and are accepted as an essential infrastructure in modern societies [7, p. xiii].

Another important characteristic that has been considered for SDIs, is that they may be components of other SDIs. Rajabifard et al. [8] propose a hierarchy of SDIs, from the corporate to the global level, and point out some relationships among these levels. Masser [9] suggests that this hierarchical composition is one of the research challenges provided by SDIs. The already approved Infrastructure for Spatial Information in the European Community (INSPIRE) directive aims to build a European SDI based on the SDIs of the Member States [10].

Some aspects of the software architecture of SDIs have already been analyzed: ANZLIC [11] describes a technical architecture, services, service providers and data storage facilities, for the Internet Framework of the Australian SDI Distribution Network. Bernard et al. [12] present an architectural view of the European SDI geoportal and associated services. GeoConnections [13] describes the Canadian Geospatial Data Infrastructure Architecture following the ISO RM-ODP information, engineering and computational viewpoints. Béjar et al. [14] have proposed an architectural style, roughly correspondent to the ISO RM-ODP engineering viewpoint, for the software

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components of an SDI.

Although SDIs include many different components, software architecture techniques have been mainly used to model their technical aspects. Nevertheless, some software architecture methods allow to address the non-technical components of systems too: RM-ODP provides the concepts and tools to address non-technical components of complex distributed systems, like SDIs, under the so-called enterprise viewpoint. The RM-ODP is being considered for the United Nations SDI technical governance framework, although this project is still in the design phase, and there are not many details yet [15]. It is also being used for the architecture implementation pilot of the Group on Earth Observations System of Systems (GEOSS), which objectives are related to those of an SDI [16].

Hjelmager et al. [17] have proposed an initial model for SDIs under the RM-ODP enterprise viewpoint (and also under the information viewpoint). Besides other differences, our paper improves their enterprise model in several aspects:

- We take into consideration the relationships among different SDIs and among the organizations participating in them.
- We relate policies with the interactions affected by them, consider explicitly enterprise object types and artefact role types and describe processes in UML.
- We use the recently approved ISO/IEC International Standard that establishes the use of UML to express the RM-ODP concepts [18].

In this paper, an approach to model some of the technical and non-technical components of an SDI using an architectural viewpoint is proposed. This approach allows to model SDIs as federations of autonomous organizations, where technical and non-technical components interact, under the guidelines and constraints of several policies, to achieve certain objectives. The RM-ODP enterprise language provides a set of well-defined concepts used to create an enterprise view on a system. This viewpoint addresses its purpose, expected behaviour and policies. There is also a standardized way to express these concepts as diagrams in the Unified Modeling Language (UML), and several proposals to formalize them if needed [19, 20].

The rest of the paper is structured as follows: section 2 presents a brief introduction to the ISO RM-ODP and its enterprise language. This is followed by the main part of the paper, section 3, where the elements of an

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architecture to model SDIs following the enterprise language of the ISO RM-ODP are described. Finally, in section 4, some conclusions and further work are described.

2. The Enterprise Language of the RM-ODP

The ISO Open Distributed Processing Reference Model (RM-ODP) provides an architectural framework to model complex environments where heterogenous information resources are distributed among different interconnected organizational domains [21, 22, 23, 24].

The RM-ODP allows to specify an Open Distributed Processing (ODP) system in terms of different, but interrelated, viewpoint specifications. A viewpoint on a system is an abstraction of that system addressing a particular set of concerns. Viewpoints simplify reasoning about a system, allowing its designers to focus on different concerns as needed. For the different viewpoints on a system, a viewpoint language is provided.

The RM-ODP provides five viewpoints: the *enterprise viewpoint*, concerned with the purpose, scope and policies of a system, the *information viewpoint*, concerned with the information handled by the system, the *computational viewpoint*, concerned with the decomposition of the system in objects and interfaces, the *engineering viewpoint*, concerned with the infrastructure required to support distribution, and the *technology viewpoint*, concerned with the chosen technologies used to support distribution. A complete specification of a given system would consist of several, related and mutually consistent, viewpoints. This paper is focused on the enterprise viewpoint.

The Enterprise Language of the RM-ODP defines the concepts and rules used to specify the enterprise viewpoint on a system [25]. The fundamental structuring concept for an enterprise viewpoint is that of *community*. A community is a configuration of *enterprise objects* describing a set of entities such as human beings, information resources or information processing systems, which is formed to meet an *objective*. An enterprise view must include at least one community, but it can be structured in terms of several interacting communities.

The scope (of a system) is 'the behaviour that a system is expected to exhibit' [25, p. 4], and it 'is defined in terms of its intended behaviour; in the enterprise language this is expressed in terms of *roles* or *processes* or both, *policies*, and the relationships of these' [25, p. 6, emphasis added]. These

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concepts are defined later in this paper, when they are used (sections 3.3, 3.5 and 3.6).

Roles, processes, and policies allow to model the behaviour of an ODP system. The enterprise objects of a community will typically fulfil different roles at different times: the same person, an *enterprise object*, can be a user and a data producer, both of them *roles*, though not simultaneously. When this person is fulfilling the role user, she can be involved in downloading certain data set, that would be a *process*, but only if she is allowed to, for instance by a certain *policy*.

To end this section, a formal issue must be highlighted: the RM-ODP standard does not recommend any notation to specify ODP systems. Nevertheless, there is an ISO/IEC International Standard to establish how to use the UML for this task [18] (UML4ODP). In this paper that International Standard has been followed.

3. SDIs in the Enterprise Language of the RM-ODP

As described in section 2, the RM-ODP provides the necessary concepts and rules to specify distributed information systems under five different viewpoints. In the next subsections we develop an approach to facilitate the modelling of SDIs from the enterprise viewpoint of the RM-ODP.

3.1. Communities

In the RM-ODP enterprise viewpoint, systems are first specified as communities and then refined as needed. As highlighted in [8, 9], SDIs are usually composed of other SDIs, with some kind of hierarchical organization. Nevertheless, other community types are also involved: for example, two environment departments of neighbour states may agree to form a new SDI, but they are not SDIs themselves. We will say that any community that is part of an SDI is a *member* of that SDI.

We may be more precise if we take into consideration a common community type in the RM-ODP: a *federation* is a type of community formed by other communities that cooperate to achieve a common objective [25]. These communities, the federation members, are bound by the contract of the federation but they keep their autonomy. As SDIs are formed by several communities to achieve a common objective, we may model an SDI as a type of RM-ODP federation.

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The relationships between SDIs and their members will typically be implemented by making some objects in the members to fulfill roles defined by the SDIs to which they belong. For instance, an SDI may require its members to have a contact point, so this SDI specifies the role 'contact point' and each member designates an object, e.g. a person or organization, to fulfill it. Nevertheless it may be useful to have a UML4ODP diagram which shows the relationships among the communities in an SDI without that level of detail. Figure 1 shows a very simple example with our proposal[1]. That diagram includes three different SDIs (INSPIRE, Spain SDI and France SDI) and two communities which are not SDIs (Spain cadaster and the Ebro basin Authority). All communities are modelled as «EV_CommunityObjects», UML classes, which are used in RM-ODP to model communities as a whole. All SDIs must define a role which extends the corresponding 'SDI members' (see section 3.3.1). To show that a community is member of an SDI, it must fulfill that SDI member role. For instance, as shown in the figure, the 'Spain cadaster' community object is shown to fulfill the role 'Spain SDI member' by means of a «EV_FulfillsRole» UML association. To show which communities are SDIs, simple notes are used.

3.2. Objectives

An RM-ODP community is built to meet an *objective*. This objective may be decomposed into *sub-objectives* if needed. Communities are specified in *contracts*. An example of a community contract which includes its objective, in UML4ODP, is shown in figure 2. In that figure, the Spain SDI is modelled as an «EV_Community», a UML component, linked to its objective, a UML class, by a «EV_ObjectiveOf» UML association. The Spain SDI «EV_CommunityObject» is also shown to illustrate the use of the «EV_RefinesAsCommunity» UML dependency with the component which expresses this community.

Based on the several definitions for the term 'Spatial Data Infrastructure' analyzed in [2, 3], we propose that the objective of an SDI is to facilitate and promote the use of electronic spatial information resources, on a stable and supporting environment, in a geographical region where different autonomous relevant organizations[2] coexist, and where it is desirable, or necessary, to

[1]UML4ODP does not address federations, so there is neither a recommended approach nor any hints on how to model them in UML.

[2]We are using organization in a broad sense, not necessarily to refer to formal or legal

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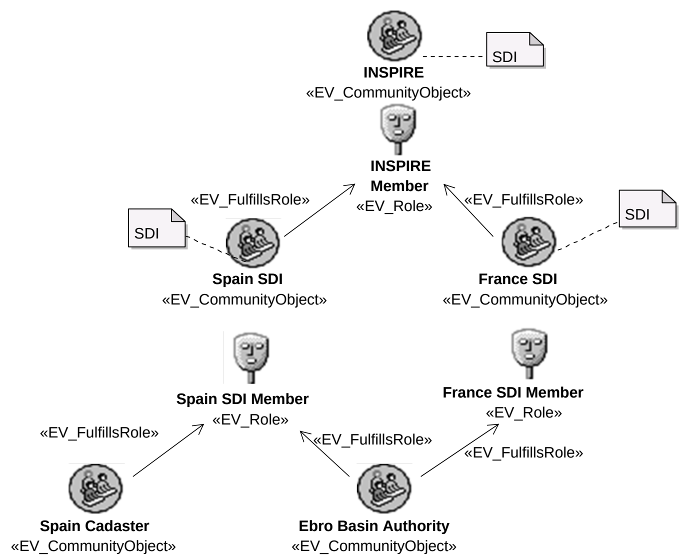

Figure 1: A diagram with an SDI and some of its members in UML4ODP

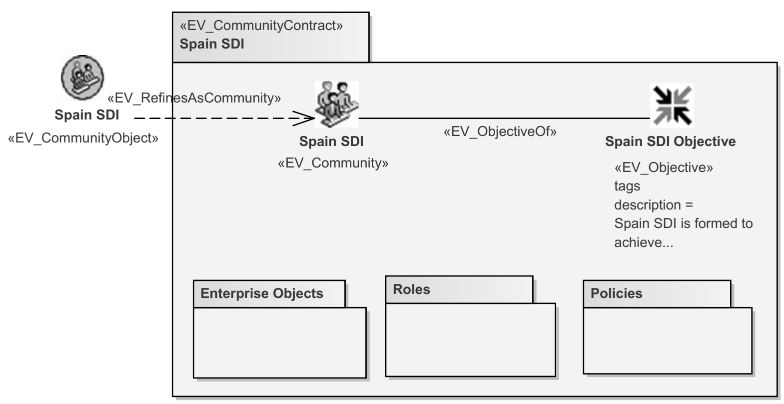

Figure 2: Spain SDI community contract in UML4ODP

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keep some of that autonomy. This objective is decomposed in these three sub-objectives:

- Facilitating the creation, discovery, evaluation, exploitation, reuse, integration, and commerce of electronic spatial data and services.
- Creating a sustainable, reliable and supporting environment, by securing the necessary funds, establishing and adopting norms and policies and providing certain fundamental assets.
- Facilitating the cooperation and coordination among relevant, autonomous organizations, with different responsibilities in different areas, scales and domains.

These sub-objectives are generic and they must be considered as a starting point for concrete SDIs to specify their own.

3.3. Roles

The behaviour of a community is specified to meet its objective. It consists of the *actions* where this community objects participate. These objects participate fulfilling the *roles* defined for the community. For instance, a person can fulfill the role of user in a certain interaction, and the role of contributor in another one. Roles in RM-ODP are identifiers for behaviours (i.e. a role is a named collection of actions, with some constraints on those actions). A given object can participate in an action, as an *actor role*, or be mentioned in an action, fulfilling an *artefact role*, or can be essential for an action, requiring allocation and possibly becoming unavailable, as a *resource role*.

Roles facilitate modelling complex and scalable environments. For instance, the system administrators in two different communities in an SDI may have very different profiles and responsibilities, but when they fulfill the SDI role of *operational body*, their behaviour is well-known. This way the interactions and processes in the SDI can be defined without the need to know which objects will be participating, as long as these objects participate fulfilling the well-known roles specified for that SDI.

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organizations. We use the term ‘relevant’ to refer to organizations with an interest in spatial data and services, either as producers, value-added providers or users.

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The rest of this section defines some actor and artefact roles that we have found adequate to meet the objectives of an SDI. We have not found it necessary to define resource roles for the abstraction level addressed in this work.

3.3.1. Actor Roles

These are actor role types found necessary to achieve the objective of an SDI as stated before:

- **User**: They exploit the spatial assets provided by the SDI.
- **Contributor**: They contribute and/or withdraw assets, i.e datasets or services, to the SDI. A contribution is a way to make some assets available to the users (not necessarily free of charge).
- **Custodian**: They create and maintain core assets, e.g. the official topographic maps of a nation, and are responsible for its quality and availability [26].
- **Governing body**: They are in charge of creating, removing and changing policies. They also participate in the decision making activities in an SDI. This role includes characteristics of the 'coordination body' defined in the GSDI cookbook and [4], the 'coordinator' in [8] or the 'executive level personnel' in [4].
- **Operational body**: They are responsible for carrying out many activities in an SDI: systems administration, technical support, quality assurance or relationships among the members. This role includes, for instance, the responsibilities of the 'catalogue administrator' and 'gateway manager' in the GSDI cookbook, or the 'operational level personnel' in [4].
- **Contact**: They represent a community in their interactions with other SDIs. This role includes some of the responsibilities of the 'broker' in [17] and participates in the formal and informal engagements among SDIs described in [4, p. 188].
- **Educator**: They are responsible for the teaching and learning activities intended to cultivate the skills, technical competence, knowledge and best practices needed to maintain and use an SDI. Educators would

hold responsibilities on information and training for the capacity building described in [27].

- **Promoter**: They are responsible for publicizing an SDI, its components, objectives and benefits, and for keeping the different actors informed of news and changes. The promotion of the SDI is an activity mentioned in the GSDI cookbook.

- **Funder**: They provide the funds needed to keep the SDI. The GSDI cookbook highlights the importance of funding, gives some examples for different SDIs, and makes some suggestions in order to ensure funding and persuade funders (p. 110-112).

- **Member**: This role models the behaviour of a community which belongs to an SDI, as a whole. It is mainly used to show the structure of an SDI (see section 3.1).

- **Communication channel**: The means used by other actors of an SDI to exchange information and to access the spatial assets. It is explicitly considered to emphasize the importance of well-defined communication mechanisms in an SDI.

- **SDI catalog**: The mechanism provided by an SDI to obtain metadata about its spatial assets. Nothing is implied about this mechanism: it can be a single service, a gateway to a network of services or a simple directory.

3.3.2. Artefact Roles

These are the descriptions for the artefact role types mentioned in the processes and interactions in this paper:

- **Spatial asset**: Any useful or valuable spatial information resource that can be made accessible to the users of an SDI. It is a generalization of very different spatial information resources (such as spatial datasets, geoportals, OGC web services or promotional stuff).

- **Core asset**: An element which is essential to achieve the objectives of an SDI. The GSDI cookbook describes ‘consistent reusable themes of base cartographic content (framework, fundamental, foundation or core data)’ (p. 10). The core asset would include these themes, but also core web services, support applications, and data models.

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- **Spatial asset metadata**: A structured description about a spatial asset.

These artefact role types are sufficient for the processes and interactions described in this paper. Nevertheless, it is expected that modelling more detailed behaviour in an SDI will requiere refinements of them, like different types of spatial assets.

3.4. Enterprise Objects

Enterprise objects model entities which are needed in the specification of a system from the enterprise viewpoint. These entities can be, for instance, human beings, legal entities, software components or data resources. They participate in actions fulfilling actor, artefact or resource roles. The same enterprise object may fulfill different roles at different moments.

These are the enterprise object types required to fulfill the role types presented in sections 3.3.1 and 3.3.2:

- **Person**: An individual human being. They can fulfill the roles of user, contributor, governing body, operational body, funder, contact, educator and promoter.

- **Team**: A group of people, usually small, with a common objective. They can fulfill the roles of user, contributor, governing body, operational body, funder, contact, educator and promoter.

- **Organization**: A stable entity formed by people with a certain purpose, and guided by a set of, typically formal, rules. It can fulfill the roles of member, user, contributor, governing body, operational body, funder, contact, educator, promoter and custodian. This is the only object type that we have found appropriate for custodianship, as this activity would require long term commitment and, possibly, a formal institution.

- **Spatial dataset**: A collection of data related to geographic locations. They can fulfill the roles of spatial asset and core asset.

- **Spatial application**: A software system that allows users to perform a set of tasks, mainly related with spatial data and metadata, possibly accessing to some spatial services. They can fulfill the roles of spatial asset, spatial application, core asset and SDI catalog.

- **Spatial service**: A software system, with an interface for other software systems, that provides operations to access to, or work with, spatial data and metadata. They can fulfill the roles of spatial asset, spatial service, core asset and SDI catalog.

- **Geoportal**: A web site mainly focused on spatial content, spatial services, and the tools to discover them. They can fulfill the roles of spatial asset, core asset, SDI catalog (i.e. if implemented as database accessible through the geoportal), and communication channel.

3.5. Policies

Policies in RM-ODP are sets of rules related to particular purposes. For example, the specification of an SDI may require that a 'standards policy' regulates the process of loading a piece of metadata in the SDI catalog. This policy would state which standards are accepted for the metadata to be loaded.

In this work, we propose a set of policies we have found relevant to an SDI. These policies will differ among different SDIs, but any SDI following the architectural proposal in this paper will implement most, if not all, of them. They are expressed in UML4ODP, as «EV_PolicyEnvelope» UML classes, in figure 3:

- **Governance policy**: it regulates the decision making and policy making activities in an SDI. Its specific rules are very dependant on the type of SDI: its size, its scope or if its legally mandated or not.

- **Role assignment policy**: it establishes the enterprise objects that may fulfill the different roles, and under which circumstances. Some simple rules are given in section 3.4, with the different types of enterprise objects described there.

- **Infrastructure policy**: it helps to enforce that an SDI and its components possess certain properties that contribute to make them a stable, reliable and supporting environment. It is composed of several policies, as shown in figure 3.

- **Standards policy**: it facilitates the exchange of information and services by the specification or adoption of certain norms.

- **Foundation policy**: this policy establishes the core assets of an SDI.

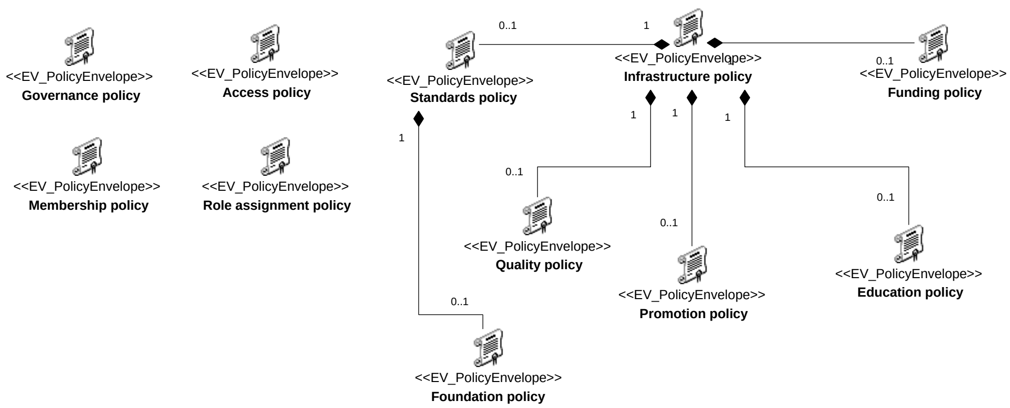

Figure 3: Policies in UML4ODP

- **Quality policy**: it regulates quality assurance in an SDI. For instance, it may require the web services to have a minimum percentage of up-time.

- **Promotion policy**: it fosters and guides the activities that make publicity for an SDI. For instance, it may obligate the members of an SDI to publicize the existence of the SDI web services in their communities.

- **Education policy**: it fosters and guides the teaching and learning activities in an SDI. For example, it may authorize the members of an SDI to use certain educational resources to train the staff in their communities.

- **Funding policy**: it establishes how the necessary funding to keep an SDI is secured. For instance, it may obligate members of the SDI to contribute funds according to their status.

- **Access policy**: it establishes the mechanisms to access and withdraw spatial assets in an SDI. This may include property rights management,

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licensing, price policies and the rights that members keep over the spatial assets they contribute (i.e. whether after a contribution they keep the right to withdraw it).

- **Membership policy**: it regulates generic aspects of the relationship among an SDI and its members, as rights and obligations or entry and exit procedures.

A simple example of the expression of one of these policies in UML4ODP is shown in figure 4, following the pattern in [18, fig 9]. In the figure we can see an «EV_PolicyEnvelope» class, SDI Standards Policy, and an «EV_PolicyValue» class, SDI Standards. These two different classes allow to separate two different uses of policy in RM-ODP: a policy value is a set of rules in force at some particular time, while a policy envelope is a set of policy values. A policy envelope may have a predefined set of policy values, or it may have a set of rules to constrain valid policy values. In the example we can see that the policy envelope states that ISO and OGC standards will be used when available in that SDI, in a «EV_PolicyEnvelopeRule» constraint, and the policy value currently in force indicates that for a certain kind of SDI services, view services, the OGC WMS 1.3 standard will be used (in a «EV_PolicyValueRule» constraint). This policy value can change in the future, for instance when there is a new version of the OGC WMS, but it will have to be in accordance with the policy envelope, unless the policy envelope is changed too. The roles and processes affected by the policy are shown with an «EV_AffectedBehaviour» dependency to the «EV_PolicyEnvelope» class. Finally, there is an interaction which changes the standards policy. This interaction is associated as the «EV_ControllingBehavior» to the policy envelope.

3.6. Interactions and Processes

Enterprise objects participate in *actions* fulfilling roles. If two or more objects participate in an action, or when a single object interacts with itself, it is said to be an *interaction*. *Processes* specify how collections of actions take place to achieve some result. Interactions are focused on the collective behaviour of communities, while processes are more focused on the achievement of certain objectives. RM-ODP allows to specify behaviour by using interactions, processes, or a combination of them, at the choice of the architect. In this work, we describe three interactions and three processes, all of them regarding fundamental behaviours in any SDI. These are the interactions:

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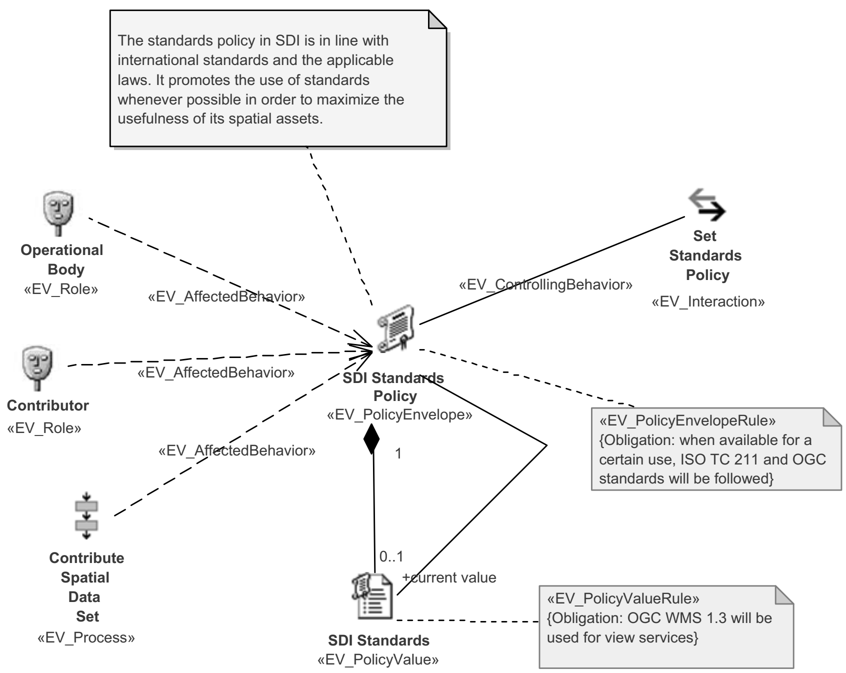

Figure 4: A standards policy expression in UML4ODP

- **Join SDI**: A community, represented by a **contact**, joins an SDI, represented also by a **contact**. The interaction is regulated by the **governance**, the **membership** and the **infrastructure** policies, and approved by an **operational body** of the SDI that is incorporating the new member. The membership policy establishes the requirements to the joining member to be admitted, and the governance policy the procedures to follow. The infrastructure policy may include certain indirect requirements: for instance, if certain quality parameter is expected to be achieved by all members, the new member must comply.

- **Leave SDI**: A community, represented by a **contact**, wants to leave an SDI, represented also by a **contact**. The interaction is regulated by the **governance**, the **membership** and the **infrastructure** policies, and approved by an **operational body** of the SDI which includes the leaving member. The membership policy determines the requirements that a member must fulfill to withdraw from an SDI, and if that is permitted.

- **Obtain access to spatial asset**: Any **user** with an interest in a **spatial asset** uses the **SDI catalog** to obtain the **spatial asset metadata**, in order to find out the requirements to access it. These requirements may involve contacting an **operational body**, e.g. to get technical support, or the **contributor** responsible for that asset, e.g. to obtain a permission. This contact would happen through an SDI **communication channel**. This interaction intends to capture the, potentially complex, actions needed for users to obtain access to spatial assets (e.g. discovering them, negotiating licenses and terms of services or establishing payment agreements), and not to model the discovery, download or use of a spatial asset. Once obtained access to a spatial asset, users will probably use it many times, but how this happens depends on the type of spatial asset.

  The **access policy** essentially exists to regulate this interaction: who can obtain access to what and how. The **infrastructure policy** may regulate some quality aspects in the access to certain assets, or some rules regarding the access to core assets.

As an example of their representation in UML4ODP, the **join SDI** interaction is shown in figure 5. This figure shows an «EV_Interaction» class, **join SDI**, associated with three «EV_Role» classes. This means that enterprise objects fulfilling these roles will be interacting. There is an «EV_InteractionInitiator», **contact**, representing the community joining the SDI, and two «EV_InteractionResponder», a **contact**, which represents the SDI, and an **operational body** that will take the necessary steps to incorporate the new community. The interaction is regulated, «EV_AffectedBehavior», by three policies: **membership**, **infrastructure** and **governance**.

Other common behaviours can be modelled as processes. Most SDIs will have many processes, but they may be very different among different SDIs. These are some common examples:

- **Contribute spatial asset**: Any **contributor** with a **spatial asset** contacts an **operational body** through an SDI **communication channel**. The contributor must provide the **spatial asset metadata**. The **operational body** checks if the contribution fulfills the appropriate policies before making it available. This process is affected by the **infrastructure** and **membership** policies, that may indicate certain requirements a spatial asset must fulfill in order to be accepted, and also certain requirements for the contributor. The **access** policy allows the operational body to check if the contribution will be accessible as required by the SDI.

- **Withdraw spatial asset**: Any **contributor** with certain rights over a **spatial asset** contacts an **operational body** through an SDI **communication channel**. The contributor must provide the **spatial asset metadata**, in order to identify the spatial asset to be withdrawn. The operational body will remove the metadata from the **SDI catalog**. This process is affected by the **infrastructure** and **membership** policies, that may indicate that certain assets from certain members cannot be withdrawn, or can be only withdrawn after certain requirements are fulfilled. The **access** policy may indicate if the contributor has the right to withdraw the spatial asset.

- **Establish/change policy**: It specifies how a **governing body** can change a policy, or create a new one. It is controlled by the **governance policy**. Refinements of this process could include the adoption of new standards (i.e. changing the **standards policy**) or changes in the laws

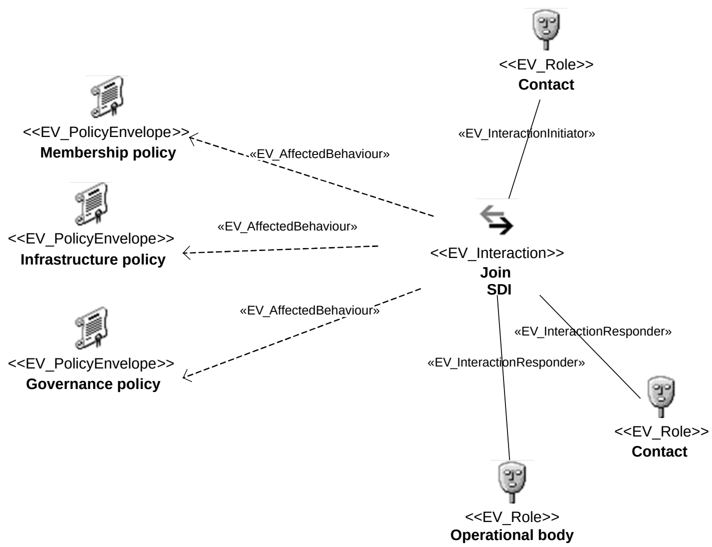

Figure 5: Join SDI interaction in UML4ODP

affecting the SDI (i.e. changing the **governance** or the **membership policies**).

As an example of their representation in UML4ODP, the activity diagram of the **contribute spatial asset** process is shown in figure 6. In that diagram, the actor roles **contributor**, **communication channel** and **operational body** are expressed by «EV_Role» activityPartitions. The steps of the process, e.g. 'validate contribution', are expressed by «EV_Step» callBehaviorActions. The artefacts referenced in the process, e.g. **spatial asset**, are expressed by «EV_Artefact» objectNodes. The process is started by a contributor, who request a spatial asset contribution to the communication channel. The channel delivers the spatial asset, and its metadata, to an operational body. The operational body validates the contribution. If it is valid, the operational body makes it available in the SDI. If not, the operational body informs of the rejection reasons so the contributor can make the appropriate changes. A real world specification would refine several of the steps of this process, for instance to specify in detail the validation. This would be done associating each refined callBehaviorAction with an «EV_Process» activity that expresses the refinement.

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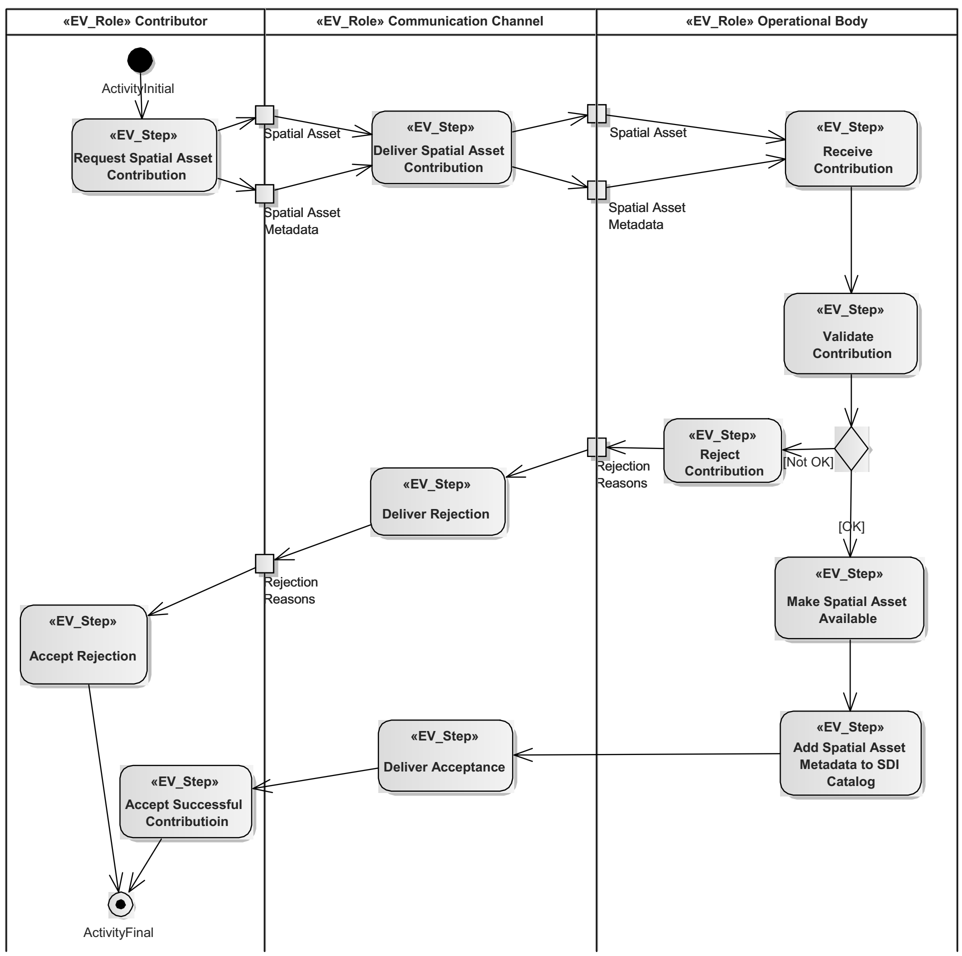

Figure 6: Contribute Spatial Asset process in UML4ODP

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4. Conclusions

This paper has presented an architectural view for SDIs, which allows to describe them as federations of communities in terms of the enterprise language of the ISO RM-ODP. The language chosen to express this view has been UML4ODP. This approach provides a systematic, graphical and formalizable technique to model SDIs, and a way to facilitate the exchange of knowledge about them among different stakeholders. Designers and researchers may apply this view to produce an enterprise specification to guide the set up of a new SDI, to plan future changes to a given one, or to document its current state, for instance as a first step towards an assessment study. As they are based on common and well-established architectural concepts, these views make it possible to compare different SDIs, from a systems perspective.

This work has also made it possible to provide conceptualizations for many terms used to describe SDIs in current research. The most significant example is the term 'SDI' itself, that we can now define on well-known concepts of the RM-ODP: an SDI is a *federation* of *communities*, which may be SDIs themselves, which *objective* is to facilitate and promote the use of electronic spatial information resources, on a stable and supporting environment, in a geographical region where different autonomous relevant organizations coexist, and where it is desirable, or necessary, to keep some of that autonomy. Although this definition looks simple, we consider that it fits well the systems currently described as SDIs, and that it is more specific and clear than the existing definitions for SDI. This paper has also advanced in the conceptualization, on RM-ODP concepts, of many other SDI terms which existed but were not typically related to any formal substrate, e.g. **user**; it has also proposed new terms for some abstract concepts that were necessary in order to model generic interactions, e.g. **spatial asset**, and has made it explicit several concepts which have been usually considered implicit, or not considered at all, like **promotion policy**.

SDIs are complex systems in constant change, with many different components, and where many actors, with different interests, necessities and degrees of autonomy are constantly interacting. Previous research has recognized this complexity by considering them under the point of view of Systems of Systems and Complex Adaptive Systems. We thus expect that the proposal in this work can be useful to model SDIs to a certain extent (e.g. fundamental roles, policies, and interactions), that is enough to set up an 'SDI game board' where the evolving interactions among its elements can be followed,

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although further research is needed to validate this point.

Regarding the use of RM-ODP, this ISO standard has provided the necessary concepts to model SDIs from an enterprise viewpoint. Taking into consideration the complexity of SDIs, we have shown that the enterprise language of the RM-ODP can be a powerful and flexible tool to address the modelling of complex and distributed systems. The use of UML4ODP has provided us with an standardized way to express the concepts in the enterprise language of the RM-ODP. Nevertheless we have found some issues with UML4ODP which deserve some attention:

- The UML4ODP standard does not address federations at all. This would have been very helpful in a situation where the distinction between federations, SDIs, and communities which are not federations, which are not SDIs, is crucial.
- It seems there is an 'impedance mismatch' between UML and the RM-ODP. Although the UML4ODP standard has managed to successfully overcome this, it has been done at the price of a certain complexity. For instance, an actor role type is expressed as a stereotyped UML Class or as an stereotyped UML ActivityPartition, while an artefact role type is expressed as a stereotyped UML Signal or as an stereotyped UML ObjectNode depending on the situation. The use of an appropriate UML modelling tool makes things easier, but we think that the UML4ODP standard complexity must be taken into consideration when evaluating its suitability for a project.

As immediate future work, we will apply the results presented in this paper to model a real-world SDI, in order both to confirm its applicability and to extend the concepts described in this paper if necessary to address new aspects of that SDI. In the longer term, we plan to address other RM-ODP viewpoints for SDIs too.

5. Acknowledgments

This work has been partially funded by the Spanish government through the projects 'España Virtual' (ref. CENIT 2008-1030) and TIN2009-10971, the Government of Aragón through the project PI075/08, the Spain National Geographic Institute (IGN) and GeoSpatiumLab S.L. The authors have also to acknowledge Akira Tanaka and Antonio Vallecillo who, by blog, e-mail

and telephone, helped us to understand some points in the RM-ODP and UML4ODP standards (of course, any mistake in this paper regarding these standards is entirely our own fault).

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