Specifying the Engineering Viewpoint of ICA's Formal Model in a Corporate Spatial Data Infrastructure

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***Abstract*— The International Cartographic Association (ICA) proposed a formal model to describe Spatial Data Infrastructure (SDI) regardless of technologies or implementations using the Reference Model of Open Distributed Processing (RM-ODP) framework. The framework consists of five viewpoints. ICA's model specified the Enterprise, Computational, and Information viewpoints, but not the Engineering and Technology viewpoints. The Companhia Energética de Minas Gerais (Cemig) has developed an SDI, called SDI-Cemig, aiming to facilitate the discovery, sharing, and use of geospatial data among employees and consumers. This paper presents a specification of the SDI-Cemig components using the Engineering viewpoint based on ICA's formal model.**

Keywords- ICA Model; SDI; RM-ODP; Engineering Viewpoint.

I. INTRODUCTION

Users access a Spatial Data Infrastructure (SDI) aiming to recover and carry out operations on geospatial data for spatial-temporal analyses and to use decision-making support mechanisms in those systems [1]. The growth in SDI creation and use derives from the increase in geospatial data available. Currently, geospatial data are generated daily by people using devices (e.g., cameras, tablets, smartphones), web systems, sensors (e.g., Global Positioning System trackers and cameras), and by initiatives of businesses and corporations to map data on Earth's surface [2]. According to Harvey et al. [3], SDIs improve the sharing and use of geospatial data and services, which helps different users of a given community.

The Companhia Energética de Minas Gerais (Minas Gerais Power Company - Cemig), a corporation comprising over 200 companies, is developing SDI-Cemig in order to help its employees and clients share and discover geospatial data. The research & development project called "Geoportal Cemig – SDI-Based Corporate GIS" is funded by a partnership between Cemig and the Fundação de Amparo à Pesquisa do Estado de Minas Gerais (Research Support Foundation of the State of Minas Gerais - Fapemig). One of the goals of this project consists in creating a method to develop corporate SDIs.

The International Cartographic Association (ICA) has proposed a model to describe SDIs by specifying three of the five viewpoints of the Reference Model for Open Distributed Processing (RM-ODP), namely the Enterprise, Information, and Computational viewpoints [4]. The other viewpoints of the RM-ODP framework, i.e., Engineering and Technology, were not described in the ICA's model.

The ICA's formal model for SDI was later extended by other researchers to describe more properly the actors and policies in the SDI [5]-[9]. According to Oliveira et al. [7], the ICA's formal model can be adapted to describe corporate SDIs, with the open possibility of creating the Engineering and Technology viewpoints.

This study presents the specification of the Engineering viewpoint for SDI-Cemig, based on the adapted formal SDI model by the ICA. The paper is structured as follows. The Section II details, briefly, studies that specify SDI through the use of the RM-ODP. Section III describes the ICA's formal SDI model. Section IV presents the specification of the Engineering viewpoint for SDI-Cemig. Section V discusses the results presented in this study and Section VI reports final considerations and possible future works.

II. RELATED WORKS

Several studies have used the RM-ODP to specify an SDI [10]-[13]. The research in [10] specifies only the stakeholders of the Namibian SDI using as model the actors specified in [4]. The proposal in [11] aims to improve the urban planning and management through the use of an SDI. The authors specify the RM-ODP Information viewpoint of an SDI, considering the inherent requirements of the urban planning. The remaining viewpoints of the RM-ODP are not specified. The framework developed in [12] specifies semantic SDI (SSDI) using the RM-ODP. Only the Enterprise, Information and Computation viewpoints are detailed. At last, [13], as [4], proposes a reference model for the marine SDI of Germany (MDI-DE) using the RM-ODP. However, in [13], only the Enterprise viewpoint is presented.

Differently from the studies cited in this section, our study presents the specification of the Engineering viewpoint from an SDI that, at the best of knowledge, has not been detailed in the SDI literature. Moreover, our specification is based on a formal model which, with exception of [10], is not presented in the studies detailed.

III. ICA'S FORMAL MODEL FOR SDI SPECIFICATION

The RM-ODP framework results from a partnership among the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC), and the Telecommunication Standardization Sector [14]. It consists of a framework to specify heterogeneous distributed systems, enabling the distribution, interoperability, portability, platform independence, and technology [15].

In Hjelmager et al. [4], the ICA proposed the use of the RM-ODP model as a reference to design and create an SDI. Its use allows modeling actors, policies [4], data semantics, objects, and features [6] required for an SDI. One advantage of using the model is the great independence of technology and implementation [4]. For example, two companies may use the same modeling to implement their respective SDIs while using different sets of technologies with no need to change the modeling.

RM-ODP comprises five viewpoints, where each represents an architectural viewpoint of the system [16]. The viewpoints do not show isolated parts of a system, but rather describe a different viewpoint of the same system. By using viewpoints, the model is specified as five smaller models, with each viewpoint accounting for specific relevant issues [14][17]. Fig. 1 illustrates a diagram representing those five viewpoints.

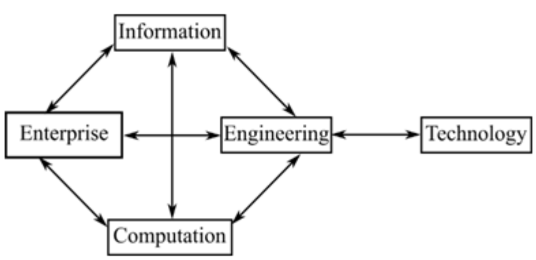

Figure 1. Viewpoints of the RM-ODP framework [4].

According to Linington et al. [17], the Enterprise viewpoint defines the scope and policies of the system, where the system requirements are defined. The Information viewpoint works with information semantics and its processing, describing the structures and types of data used. The Computational viewpoint defines a distribution by functionally breaking down the system into objects that interact in interfaces. It describes the features provided by the system and objects are built based on its features. The Engineering viewpoint is built based on the mechanisms and features required, supporting interactions distributed among the objects that make up the system. It describes the distribution of processing and communication among its several objects. The Technology viewpoint is related to the needs of the system regarding technology, describing the technologies required for processing, features, and information visualization.

This study approaches only the Engineering viewpoint of SDI-Cemig. The detailed definitions of the Enterprise, Information, and Computational viewpoints can be found in [8][9]. The Technology viewpoint is beyond the scope of this study and shall be specified in future works.

A. *Engineering Viewpoint*

The Engineering viewpoint aims to identify and specify interactions among distributed objects, focusing on their communication, organization, and distribution. It comprehends the distribution of compounds and the connections among them, besides defining common roles to support the distribution of components [18].

One advantage of using the Engineering viewpoint is creating a neutral and independent model not bound to specific technologies. That provides freedom in the choice of available and preferred technologies in an organization wishing to implement a given project. Along with the idea of a neutral model, a certain technology may be more easily replaced in case the organization decides to change it for private internal reasons [19].

Below, there are some components that are part of the Engineering viewpoint, according to [17], which were used to model SDI-Cemig in Section IV.

Basic Engineering Object (BEO) corresponds to the smallest representation when specifying the modeling. It is a special type of object in the Engineering viewpoint that represents a computational object defined in the Computational viewpoint that may also represent an actor, human or not, in the system. BEOs represent abstractions of elements that make up the system.

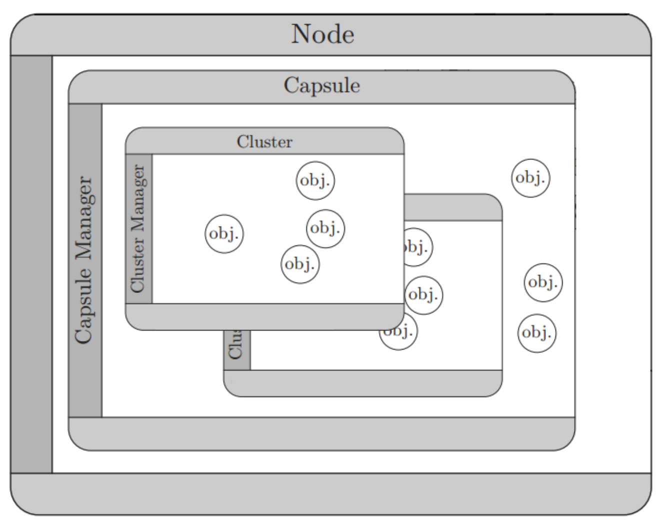

Figure 2. Viewpoints of the RM-ODP framework [4].

Fig. 2 illustrates the organization of objects in the Engineering viewpoint. A hierarchy can be seen among objects in the viewpoint. For example, within a Node there are Capsules, within a Capsule there are Clusters, and within a Cluster there are BEOs.

A cluster consists in a collection of BEOs grouped into similar functions and having lifecycles in the system [18]. A capsule represents a unit independent of processing or storage that is able to support an object collection. They are isolated from each other so as to ensure a capsule does not directly interfere with another. The node represents a physical or virtual object capable of processing, communication, and storage. It may represent a computer, the assembly of several devices that together determine a unit, a virtual machine in a computer, as long as the element has the capabilities mentioned above. They also have a high degree of isolation [17].

The structure of components in the Engineering viewpoint is split into components isolated from the capsule element. Therefore, mechanisms must be used in the communication among elements in distant structures. To that end, a communication channel structure is employed [19].

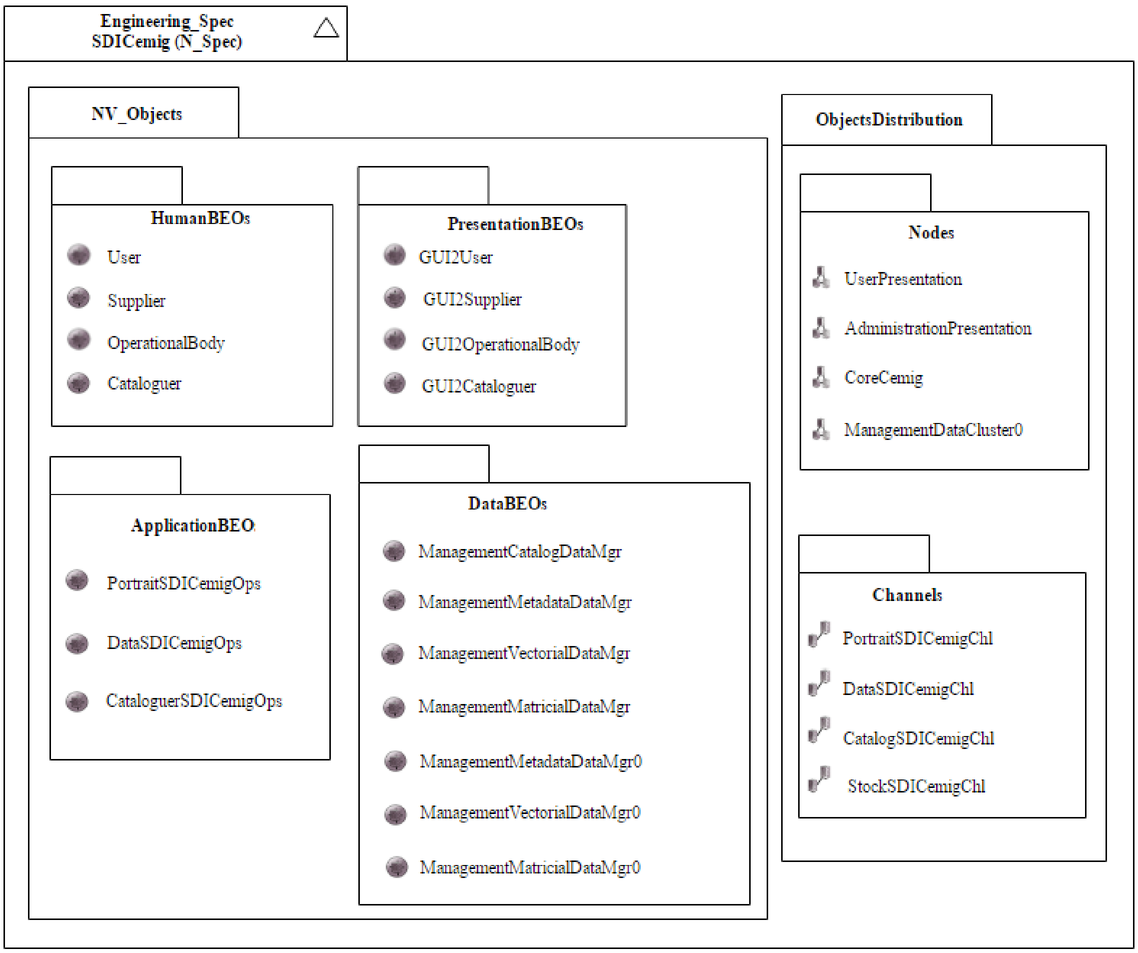

Figure 3. Overall organization of Engineering objects in SDI-Cemig.

Communication channels represent a transparent communication infrastructure, which allows objects in the Engineering viewpoint to interact, and are commonly used in the communication among BEOs of different nodes. A channel often does not need to be specified in detail since they are implemented at a lower level and the goal of the channel is to represent a communication among elements [17].

IV. Engineering Viewpoint of the SDI-Cemig

As described in Section I, Cemig seeks to develop an SDI, called SDI-Cemig, to help its employees and clients discover, share, and use geospatial data and services. This Section describes the Engineering viewpoint of SDI-Cemig. The Technology viewpoint is beyond the scope of this study, thus, it will not be detailed, while the Enterprise, Information, and Computational viewpoints of SDI-Cemig have already been described in [8][9].

The modeling of SDI-Cemig used ICA's adapted formal model for SDI. In order to create and name the elements, the examples provided by [17] when detailing the Engineering viewpoint were used as reference. The notation used terms that had meaning closer to their functionality. Names begin with a capital letter and the next words are never separated with spaces, also beginning with a capital letter. Since some components would have similar or even the same names,

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prefixes and suffixes were used in the nomenclature to differentiate their functionalities.

The overall organization of the specification of the Engineering viewpoint for SDI-Cemig is shown in Fig. 3. That figure represents the elements of the viewpoint grouped according to the functionalities of their objects. The overall organization represents a global view of the components of the Engineering viewpoint and is organized into two divisions: *ObjectsDistribution* and *NV_Objects*.

The division *NV_Objects* groups objects represent the basic elements, represented by BEOs, which are grouped into packages of similar functions. The objects were grouped into four packages: *HumanBEOs*, *ApplicationBEOs*, *PresentationBEOs*, and *DataBEO*.

The package *HumanBEOs* includes the actors that take part in the application, defined as: *User*, *Supplier*, *OperationalBody*, and *Cataloguer*. In the package *PresentationBEOs*, the BEOs represent the interfaces for the actors included in the package *HumanBEOs*. In its nomenclature, the prefix GUI2 (graphical user interface to) is added to the corresponding name in the package *HumanBEOs*. Therefore, the components of the package *PresentationBEOs* were described as: *GUI2User*; *GUI2Supplier*; *GUI2OperationalBody*; and *GUI2Cataloguer*.

The package *ApplicationBEOs* represents the features actors in SDI-Cemig may use in its functioning and administration. They represent three roles found by [9] that are required for the functioning of SDI-Cemig. The suffix Ops (Operations) is added to its nomenclature in each of its components. The components created were: *PortraitSDICemigOps*; *DataSDICemigOps*; and *CataloguerSDICemigOps*.

Finally, the package *DataBEOs* has BEOs related to information of the database. The package has components with roles in data storage and management. The suffix DataMgr (Data manager) was adopted in its nomenclature.

One way of improving the performance of information processing is to use object replication in a seamless way [16]. It can be seen that some elements have the number zero after the DataMgr suffix. This number indicates that the component is a replication of the component of analogous name and its goal is to reach better performance in the use of the application. The following objects of the *DataBEO* package were duplicated: *ManagementMetadataDataMgr*, *ManagementVectorialDataMgr*, and *ManagementMatricial-DataMgr*. It can be seen that the component *ManagementCatalogDataMgr* was not replicated since it is a component with catalog functionality and does not deal with large information volumes.

The second division, *ObjectsDistribution*, has components that represent the logical distribution and communication. It is made up of two packages: Nodes and Channels. The package Nodes represents a set of Node elements defined for the system, whose definition can be found in Subsection 3.*A*. For SDI-Cemig, four Nodes were defined: *UserPresentation*; *AdministrationPresentation*; *CoreCemig*; and *ManagementDataCluster0*.

The package *Channels* used the suffix Chl (Channel) in its nomenclature. The package aims to perform the communication of the components since the Nodes are isolated and need a means to communicate. The following channels were defined: *PortraitSDICemigChl*; *DataSDICemigChl*; *CataloguerSDICemigChl*; and *StockSDICemigChlDistribution* of Engineering Objects of SDI-Cemig.

According to Becerra et al. [19], the Engineering viewpoint specifies a communication infrastructure that must support the distribution of objects of the Computational viewpoint with no regard for the choice of technologies to implement it. Fig. 4 presents a version of the distribution of compounds of the Engineering viewpoint in SDI-Cemig grouped according to their interactions with other computational objects and packages grouping them. According to Linington et al. [17] Engineering objects represent in an abstract way the distribution and organization of the system, enabling a technology-independent modeling.

The administration of Engineering objects in SDI-Cemig were grouped into five groups: *HumanBEOs*, representing actors specified in the Enterprise [8] and Computational [9] viewpoints, namely: *UserPresentation* - represents the interfaces used by the actor *User*; *AdministrationPresentation* - represents the interfaces among the actors that manage the system; *ManagementDataCluster* - represents performance functionalities with the use of data replication; and *CoreCemig* - represents the system’s processing core. *CoreCemig* is subdivided into *ApplicationCluster* - responsible for the system’s features, *ManagementCatalogCluster* - responsible for a catalog of information available in the application, and *ManagementDataCluster* - responsible for the storage of data in the system.

The Engineering objects of the group *HumanBEOs* represent objects defined in the Enterprise viewpoint, each with its own access interface. Each client of the system has its own presentation layer with an analogous name. For instance, for the object Supplier of SDI-Cemig, there is an object in the presentation with the name GUI2Supplier.

The communication among the objects in the clusters *UserPresentation*, *AdministrationPresenttion*, and *ApplicationCluster*, the latter representing the system features, is performed through channels since they are in different Nodes. As shown in Fig. 4, there are three communication channels among the presentation clusters and feature cluster. *PortraitSDICemigOps*, *DataSDICemigOps*, and *CataloguerSDICemigOps*.

The channels are responsible for the communication between the presentation and feature layers contained in the application cluster. The link of each component to a given object and its required interfaces is based on the Computational viewpoint created by Oliveira et al. [9].

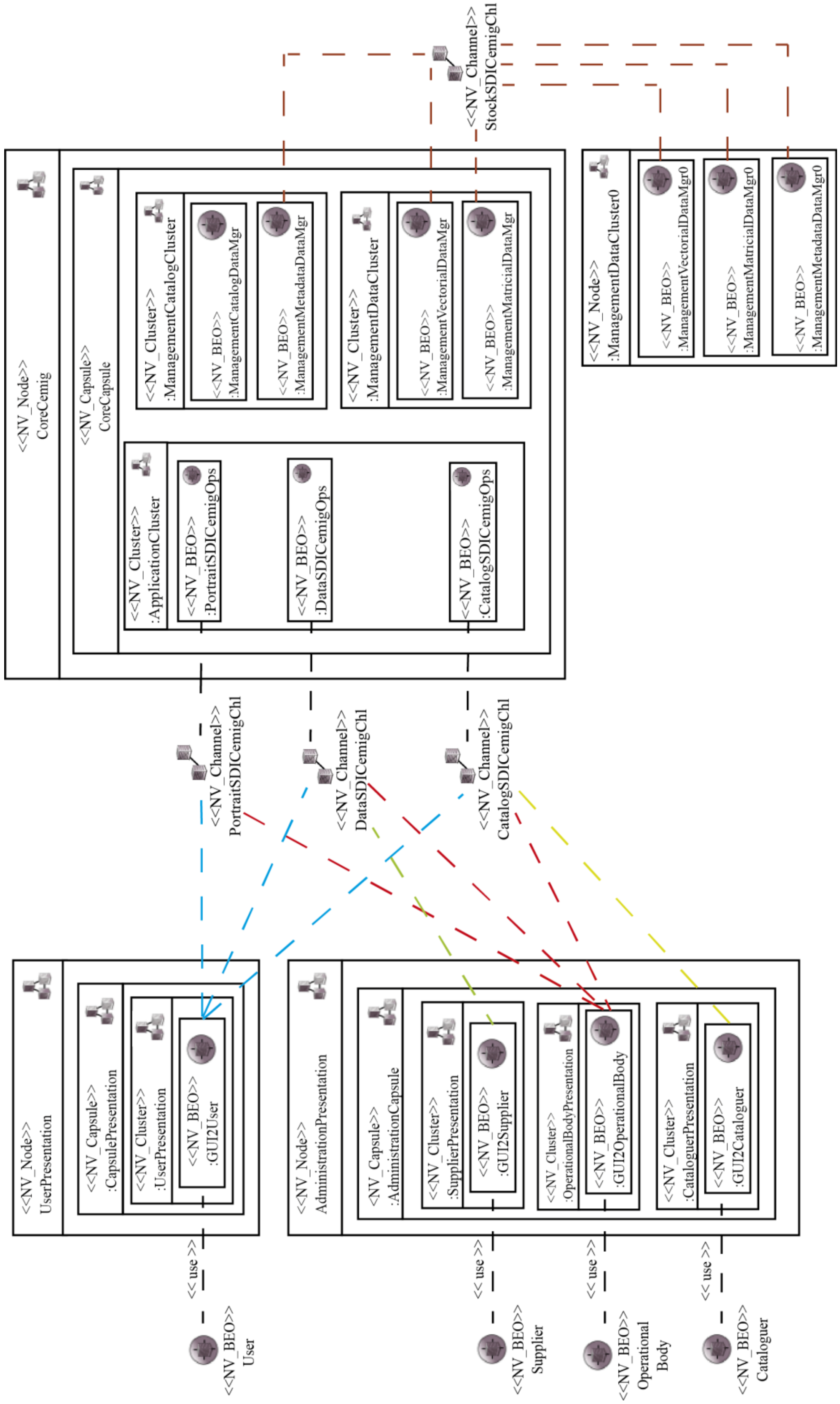

Figure 4. Engineering viewpoint of SDI-Cemig.

The channel *PortraitSDICemigChl* is responsible for performing the communication targeted at *PortraitSDICemigOps*. It fulfills requests coming from *GUI2User* and *GUI2OperationalBody* for map visualization and comprises the following interfaces: *GetMap_WMS*, *GetFeatureinfo_WMS*, and *GetCapabilities_WMS*.

The channel *DataSDICemigChl* performs the communication to *DataSDICemigOps* serving the interfaces *GUI2User*, *GUI2OperationalBody*, and *GUI2Supplier*. It plays a role in transmitting geographic information. Interfaces included: *GetPropertyValue_WFS*, *DescribeCoverage_WCS*, *GetCoverage_WCS*, *GetFeature_WFS-G*, *DescribeFeatureType_WFS*, *DescribeFeatureType_WFS-G*, *GetCapabilities_**, and *Transaction_**. The channel *CatalogSDICemigChl* fulfills the requests of *GUI2User*, *GUI2OperationalBody*, *GUI2Supplier*, and *GUI2Cataloguer*. The channel fulfills requests related to the SDI catalog. It serves the interfaces *GetRecords_CS*, *GetRecordbyID_CS*, *GetCapabilities_CS*, *GetRecords_CS*, *Transaction_CS*, and *Harvest_CS*.

V. Discussion of Results

ICA's model brings together a set of basic concepts that an SDI requires to work. The creation of the Engineering viewpoint for SDI-Cemig is a continuation and extension of the studies by Oliveira et al. [8][9] on the specification of the Enterprise, Information, and Computational viewpoints for a corporate SDI. As in the cited studies, the Engineering viewpoint described in the present study meets the basic requirements (e.g., enabling the discovery, recovery, sharing of geospatial data) of an SDI.

The Engineering viewpoint comprises structurally isolated nodes, i.e., nodes that work independently. Therefore, a failure in one component does not directly lead to a failure in another component. In case of a component being restructured, the others do not need to be adapted, since the communication is performed through channels and the new structure only needs to use the same communication structure of existing channels. Regarding the components, the system may receive new features through the creation of new objects and communication channels.

According to Oliveira et al. [9], the model applied in the specification of the SDI-Cemig can be used to build others corporate SDIs. It is observed that the SDI-Cemig has a restriction in the proposed specification, that is, it does not have geoprocessing services for a production of new geospatial data.

The viewpoint proposed in this work constitutes a continuation of this specification, maintaining the proposal for widespread use. The specification is proposed in such way that the new corporate SDIs implementations fit with the above-mentioned restriction. If there is the need to include new geoprocessing services or modifying existing one in the SDI, the model allows the expansion of functionality in the specification through the creation of new components.

This study, together with [8] and [9], present, at the best of our knowledge, the most complete specification of an SDI existing in the literature, approaching 4 of 5 of the RM-ODP viewpoints. Furthermore, our case study is based on a corporate SDI, whose kind is not sufficiently discussed in the literature.

VI. Conclusion and Futurework

By specifying the fourth viewpoint of the ICA's model, SDI-Cemig now has four viewpoints specified: Enterprise; Information; Computational; and Engineering. Since the RM-ODP framework comprises five viewpoints, only the Technology viewpoint still has to be specified, which, as the Engineering viewpoint, is not approached by ICA's SDI formal model. It must meet the requirements of the viewpoints already created and the company's technological availability.

The specification of the Engineering viewpoint for SDI-Cemig suggests that a similar specification may be used in other corporate SDIs, particularly of companies in the power sector. In case changes are required, the construction of the specification in modules enables the required adaptation to include new features. The specification of SDI-Cemig using ICA's adapted SDI formal model may help researchers and designers who wish to model SDIs based on the ICA's model even if they comprise a different SDI level.

Intended future works include specifying the Technology viewpoint of SDI-Cemig while checking it fits the viewpoints already created. After its specification, the specification will contemplate the five viewpoints of the RM-ODP model.

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