DEVELOPMENT OF GEOPROCESSING APPLICATIONS FOR THE PANTANAL USING AUTOMATED COMPOSITIONS OF WEB SERVICES

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Abstract

This paper presents an approach to develop geo-processing applications for the Pantanal region using automated compositions of geographic Web Services. The procedure for the automatic construction of these compositions is based on rules of geo-data quality requirements which indicate the conditions for geo-data use by a geo-processing functionality. These rules can be defined to describe geospatial characteristics to select suitable geo-processing services for use in the Pantanal region. Therefore this approach produces more robust and reliable service compositions, generating better quality geo-data when compared with other composition approaches.

Key words: Geographic Web Services. Geo-processing. Geo-data quality. Pantanal.

Resumo

Desenvolvimento de aplicações em geoprocessamento para o pantanal usando composição automatizada de serviços geográficos

Este trabalho apresenta uma abordagem para construção de aplicações em geoprocessamento, para a região do Pantanal, através da composição automatizada de *Web Services* geográficos. O procedimento para construção automatizada destas composições é baseado em regras semânticas de requisitos de qualidade de geodados que indicam as condições de uso de um geodado por uma funcionalidade de geoprocessamento. Regras de requisitos de qualidade caracterizando a região do Pantanal podem ser utilizadas para seleção de serviços de geoprocessamento adequados ao uso naquela região. Desta forma, a abordagem proposta permite a criação de composições de serviços mais robustas, confiáveis e capazes de produzir geodados de melhor qualidade, quando comparada com outros métodos de composição automatizada de serviços.

Palavras-chave: *Web Services* geográficos. Geoprocessamento. Qualidade de geodado. Pantanal.

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INTRODUCTION

The achievement of complex applications in geo-processing requires collaboration among institutions to perform different production activities of geo-data. Such an interaction among institutions defines a process whose objective is to execute the objectives of the application where each institution participates as a producer and consumer of geo-data.

The Service Oriented Architecture - SOA (ERL, 2004) allows the automation for the execution of these activities. SOA is a distributed computer architecture where high level functionalities are implemented by distributed software components called "Service", connected by a communication protocol. In the geo-processing context, services enable the standard and controlled geo-data access as well as to the geo-processing and spatial analysis procedures, independently to its geographic localization and to the computational environment of the provider institution. Geo-processing applications can be implemented in this architecture by the combination of these services. Languages for the process specifications, such as e.g. WS-BPEL (OASIS, 2010) allow the manual definition of these service compositions. When however the number of available services becomes bigger, the process of manual construction of these compositions gets more difficult. The localization, selection and integration activities of the component services become more complex.

Planning methods in Artificial Intelligence (AI) are used by research lines aiming to automate this composition process (RAO; SU, 2004). At these solutions, semantic descriptions of services are used to characterize the functional capacity of each service, indicating its utility as a component of a composition. Several proposals for the automated composition of services based in AI planning techniques can be found in the literature (SIRIN, 2004; YE; CHEN, 2006; CONSTANTINESCU et al, 2005; DONG et al, 2007; KO et al, 2008; CHAFLE et al, 2007). Lemmens et al (2006) and Yue et al (2007) present adaptations of these approaches of composition for the geo-processing context.

The focus at the semantic description of the services in these approaches does not characterize adequately the qualitative restrictions in the interactions among the services of a composition. Individual conditions of geo-data found during the execution of a service composition may derail or compromise the results produced by geo-processing and spatial analysis procedures. Remote sensing images from the Pantanal with clouds, obtained at inappropriate configurations of sensor angles or captured from highly inundated regions, are inadequate geo-data examples.

Such conditions may be inherent to the geo-data production process. The construction of new service compositions however, defines dynamically those contexts not foreseen for the use of geo-data, propitiating also the emergence of these incompatibilities. The applicability of spatial analysis, geo-processing and remote sensing procedures depends on each context. The Pantanal region exemplifies this dependence, since its geographical localization, its climatic, hydrologic and phyto-physiognomic characteristics restrict and impose adaptations to the achievement of analysis procedures.

The execution of compositions of services built up without considering the possibility of occurrences of such incompatibilities could generate incorrect and low quality data.

This study presents an approach for the development of geo-processing applications for the Pantanal region, through the automated construction of compositions of geographic services, capable to treat such incompatibilities. Relevant characteristics for the evaluation of the usability of geo-data for a certain analysis procedure are modeled as quality attributes of geo-data. Such attributes allow the construction of rules for the semantic description of data quality requirements, which must be considered so that the execution of each participating composition service is successful and consequently of the entire composition. In the context of the Pantanal region, the rules allow the selection of more adequate services and the generation of information subsidizing an auditing on the execution of service composition, permitting an evaluation of the quality from the geo-data generated.

The knowledge base formed by rules of quality requirements and attributes and specialized algorithms, implemented in form of services, permits the recording and reuse of knowledge from this region.

OBJECTIVE

This work presents an approach for the construction of geo-processing applications at SOA architecture for the Pantanal region, from the automated composition of geographic services. This automated composition is based on AI planning algorithms and on rules for the semantic description of quality requirements of geo-data. The definition of quality rules and attributes characterizing geo-data from the Pantanal region, allows the standardization and systematization on the use of criteria and of services to process geo-data from this region. These compositions can be stored in order to increment a knowledge base on geo-processing applications.

MATERIAL AND METHODS

GEOGRAPHIC WEB SERVICES

Geo-processing functionalities can be implemented as services on the Web, according to two main standards. The W3C (World Wide Web Consortium) defines a Web Service as a software projected to support direct interaction among machines distributed and interconnected by a communication system (W3C, 2010). The description of the behavior from this software is done by the description of its interface, i.e. in terms of available operations, input and output parameter types of these operations and access protocols. The WSDL (Web Service Description Language) is used for the preparation of documents for the description of services (W3C, 2010a). The automatic processing of a document in WSDL produces programs with syntactic treatment capacity of messages from a service. The interaction with a service is done by exchange of messages, normally in SOAP format (W3C, 2010b). The interaction by messages hides the internal details of a service, allowing that it is used independently of the software or hardware platform where it was implemented.

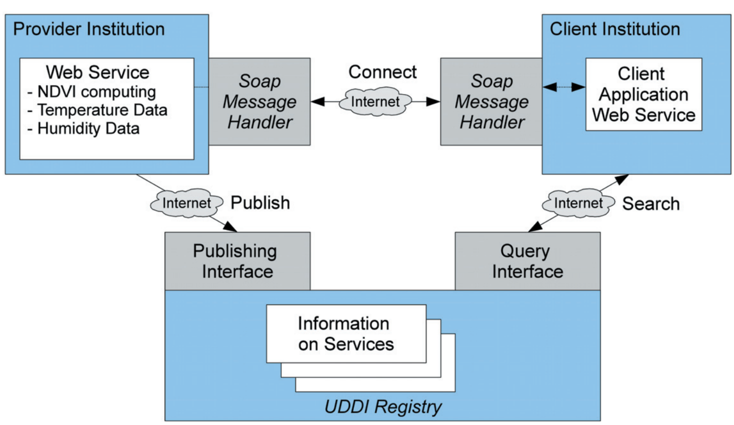


Figure 1 – Architecture elements of Web Services Standard W3C

In the Web Services architecture defined by W3C (Figure 1), provider institutions implement and supply access to a set of high level functionalities by Web Services. These institutions can optionally record information about these services in UDDI catalogues (W3C, 2010). These catalogues ease the search for available services by user institutions. Through information from UDDI catalogue and by the description of the behavior of a service in WSDL, a client application can interact adequately with a Web Service.

The Open Geospatial Consortium (OGC), which is the responsible organization to define and promote the use of geo-spatial standards, specified a model of distributed computation based on Web, aiming to make its use more efficient at applications on geo-referenced data (PERCIVALL, 2003). This specification describes a series of services on geo-processing standards. Besides the services, the OGC specifies a series of data formats and protocols which facilitate the exchange of geo-data. The WMS (Web Map Service), WFS (Web Feature Service), WCS (Web Coverage Service) and WPS (Web Processing Service) are important service specifications defined by the OGC. WMS is a service for geo-data presentation used for the generation of maps with customizable graphic characteristics. WCS and WFS are access services to matrix and vector data respectively. WPS is a general interface for the access to functionalities of geo-processing.

The standards of services defined by OGC are more specific and complex than those defined by W3C. The W3C proposal has a stronger support from the Information Technology (IT) industry, and consequently a higher amount of solutions and aggregated technologies. The standardization of formats for data exchange in the OGC proposals allows a higher syntactic interoperability on the use of geo-data. An unification effort of these two proposals has been made jointly by W3C and OGC (W3C, 2010c). This work assumes that the services have an interface described in WSDL.

AUTOMATED COMPOSITION OF GEOGRAPHIC SERVICES

The approach considered in this study for the automated construction of a service composition, assumes that the types of geo-data from the input and output of a service indicate implicitly its functionality. Additionally, quality parameters of geo-data indicate the general conditions for use of geo-data for a consumer service. These two geo-data classification perspectives are the basis to model the problem of service composition as a problem of conditional planning.

SEMANTIC DESCRIPTION OF GEO-DATA TYPES

The construction of a service composition based on the combination of input and output of service data is supported by an ontology of data types. An ontology is a model of concepts of a dominion and its interrelationships (McGUINNESS; VAN HARMELEN, 2004). The semantic description of input and output parameters of services is made associating these parameters to concepts of this ontology. The ontology used in the composition of services describes formally concepts associated to geo-data types, allowing an automated evaluation of relations among these concepts.

In this work, the concepts or semantic types of geo-data supply the semantics of the elementary geo-data units changed between the composition services. These elementary units are formed by a set of geo-referenced units, presenting the same semantic type of spatial and non-spatial attribute. The ontology models the semantic types of data, its dependencies to other types as well as its spatial and non-spatial attributes.

Figure 2 illustrates how the geo-data type NDVI, associated to the Normalized Difference Vegetation Index can be described at the ontology constructed in this work. The semantic type NDVI is defined as a specialization, through restrictions of semantic types *Image* and *ParameterizedGeoDataType*. NDVI is an *Image* type with a non-spatial attribute of type *NormalizedDifferenceVegetationIndex* and a spatial generic attribute associated to matrix data of type *CellGeometry*. NDVI is also a *ParameterizedGeoDataType*, which depends on a parameter with function *NearInfraRedSpectralBandParameter* and another with function *RedSpectralBandParameter*.

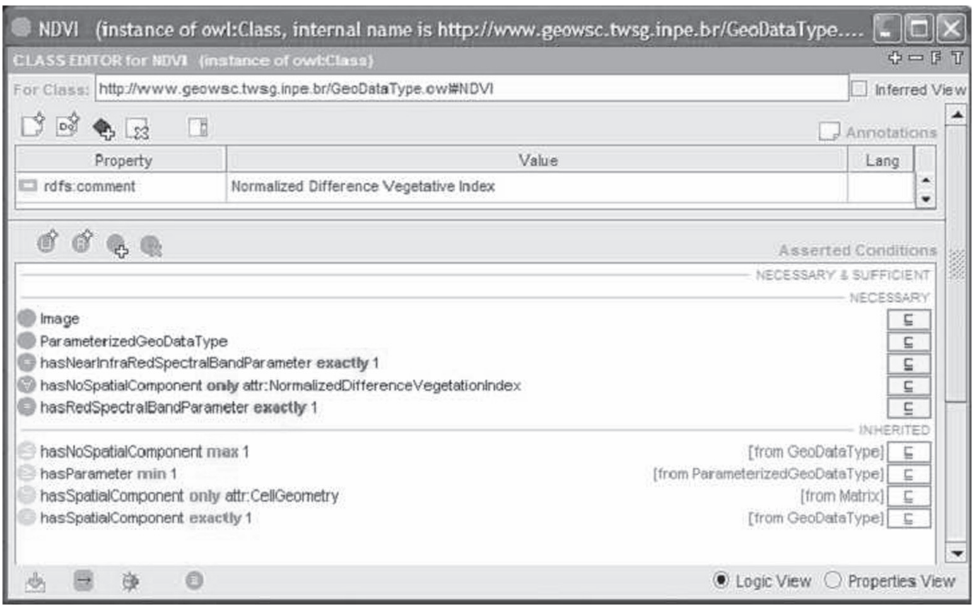
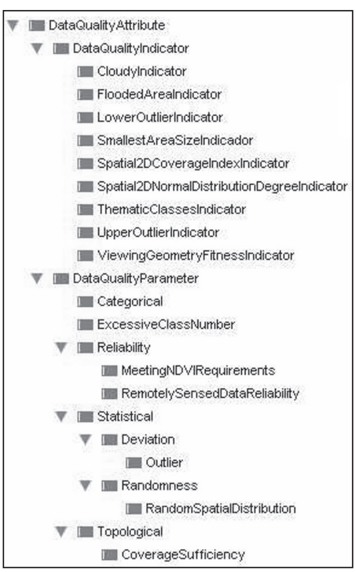


Figure 2 – Description of semantic geo-data *NDVI*

QUALITY REQUIREMENTS OF GEO-DATA FROM GEOGRAPHIC WEB SERVICES

Semantics of geo-processing services which transforms an input data into a new type of output data, can be described implicitly through the types of these parameters. Services that could be characterized on this way, are called "Services of Information Transformation". The identification of utility from these services in a certain place of the composition can be made from the type of data required at that point. So for instance there are services for the calculus of different vegetation indices generated from sensor data. On the other hand, geo-processing services which don't perform the transformation of data types, cannot have its semantic inferred by its input and output types of parameters. Services for the scale transformation and image processing belong to this category. In this case these services execute transformations on the properties of an instance from a geo-data, keeping its type. In order to decide on the inclusion in the composition of services that execute this second type of transformation, it is necessary to describe when these transformations are needed. To do that, we considered the pre-requisites for the reliable execution of a geo-data consumer service.

The reliable realization of some procedures in geo-processing depends on the conditions for the use of data. If the conditions for the use are not adequate, in some situations it is possible to realize procedures for its adequacy. In this work it is assumed that these conditions define data quality requirements indicating the need or not for the execution of transformation procedures from properties of geo-data. Since these needs depend on individual characteristics of each geo-data instance, the decision on the service execution or not of transformation from properties can just be made during the execution of the service. In the composition these services are preceded by conformity tests, needed to evaluate the conditions for data use. These conditions are expressed in terms of attributes of data quality. The values for these attributes are calculated during the execution of the composition from services which implement procedures of spatial analysis. Quality requirements of geo-data are described by expressed semantic rules using these attributes, which determine the acceptable values from these attributes which allow the use of geo-data by a service. Figure 3 presents the rules on SWRL (HORROCKS et al., 2004) for the description of data quality requirements to calculate the NDVI. The rules are expressed in terms of quality attributes of data organized in the taxonomy *DataQualityAttribute* (Figure 3a). These rules reflect the dependency of different factors (JACKSON; HOUTE, 1991) for the NDVI calculus. The level of inundation for the area under study is an external factor considered on the rule *MeetingNDVIRequirements*. The rule *RemotelySensedDataReliability* describes the inherent factors to remote sensing, the level of cloud coverage and the degree of adequacy of the geometric satellite configuration during image acquisition.




```
MeetingNDVIRequirements(?geodata, dqronto:True) ←
        config:MaximumFloodedAreaDegree(config:processo, ?MAXFLOODEDAREADEGREE)
        ∧ FloodedAreaIndicator(?geodata, ?FLOODEDAREADEGREE)
        ∧ floatValue(?FLOODEDAREADEGREE, ?floatFLOODEDAREADEGREE)
        ∧ swrlb:lessThan(?floatFLOODEDAREADEGREE, ?MAXFLOODEDAREADEGREE)
        ∧ RemotelySensedDataReliability(?geodata, dqronto:True)

RemotelySensedDataReliability(?geodata, dqronto:True) ←
        config:MaximumCloudyDegree(config:processo, ?MAXCLOUDYDEGREE)
        ∧ config:MinimumViewingGeometryFitnessDegree(config:processo, ?MINVGFDEGREE)
        ∧ CloudyIndicator(?geodata, ?CLOUDYDEGREE)
        ∧ floatValue(?CLOUDYDEGREE, ?floatCLOUDYDEGREE)
        ∧ swrlb:lessThan(?floatCLOUDYDEGREE, ?MAXCLOUDYDEGREE)
        ∧ ViewingGeometryFitnessIndicator(?geodata, ?VGFDEGREE)
        ∧ floatValue(?VGFDEGREE, ?floatVGFDEGREE)
        ∧ swrlb:greaterThan(?floatVGFDEGREE, ?MINVGFDEGREE)
```

A B

Figure 3 – (a) Ontology of quality attributes of geo-data (b) SWRL rules defining data quality requirements

AUTOMATED SERVICE COMPOSITION

The automated construction of a Web Services composition identifies the insertion point of transformation of information, transformation of properties and of metric extraction from geo-data, using as criteria its roles within a plan for the conditional execution of services (Figure 4) (RUSSELL; NORVIG, 2003). The non-attendance of quality requirements by a geo-data instance, indicates the need of a transformation of its properties to meet the needs of consumer service. The evaluation of attendance to the quality requisites requires that metrics are extracted from geo-data instance, by services which implement spatial analysis procedures and manipulation of meta-data. The values of these metrics must be tested for the identification of non-attendance of the requisites. The composition mechanism prepares contingency plans formed by services of properties transformations to treat possible non-conformity occurrences. The expressions of conformity test are constructed from the rules of quality parameters and quality requisites, as shown on figure 5. Through quality indicators present in a rule, it is possible to determine which quality indicator services must be called on.

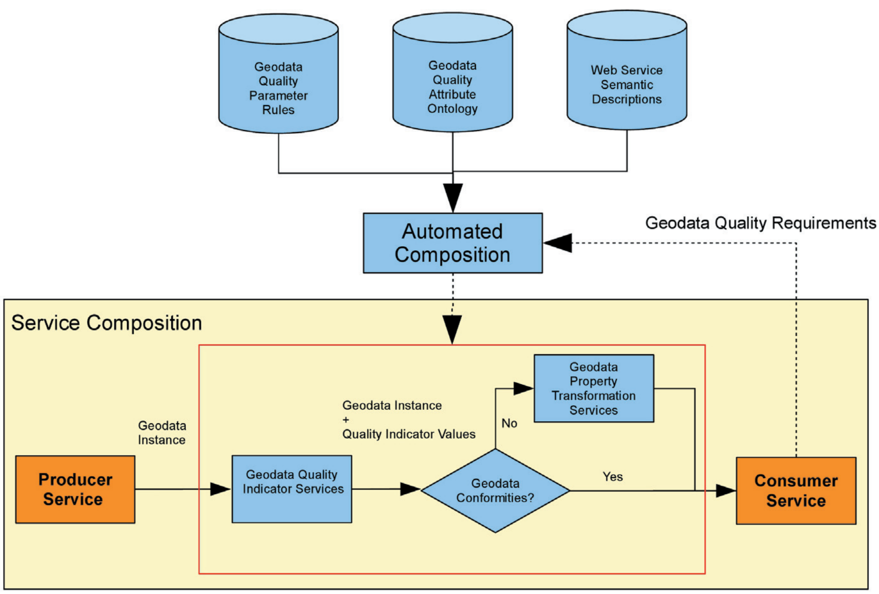


Figure 4 – Participation of quality indicator service and services for transformation of properties in a composition

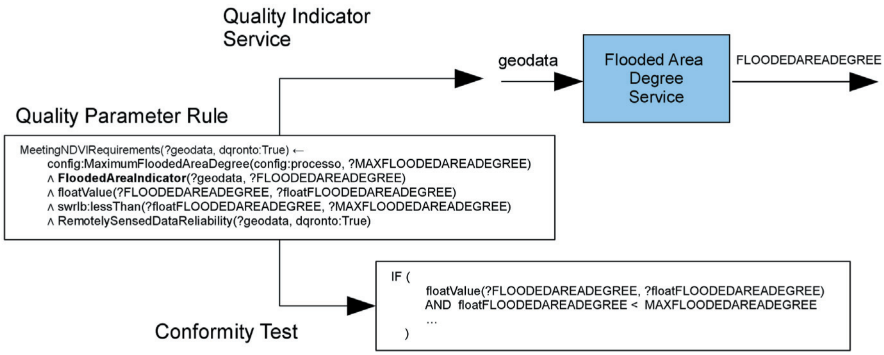


Figure 5 - Example of inference from elements of the rule composition from the quality parameter of geo-data

COMPOSITION OF SERVICES TO PROCESS GEO-DATA FROM THE PANTANAL

The Pantanal biome, located in Central-West Brazil occupies an area of approximately 138,183 km^2 (SILVA; ABDON, 1998). The richness of variety from its animal and vegetal species is determined by its climatic, hydrologic and geographic characteristics, made this region the target area of many studies. The GIS (Geographic Information Systems) are the basis to perform these studies, allowing the processing of different geo-referenced information.

At the approach adopted in this work, these same activities are performed by distributed processing based on SOA architecture. A mechanism of automated service composition allows the generation of a service execution plan adequate to the production of a type of interest data. A knowledge base containing information on the attributes and quality requirements, semantic data and service description supplies the information needed for the composition mechanism.

In this work the knowledge base was assembled for use in a case study illustrating the application of the approach proposed in the calculation of NDVI, from NOAA/AVHRR 3 data for the Pantanal region. Services with the functions of information transformation, property transformations and extraction of metrics were identified. Tables 1, 2 and 3 present the services, quality indicators and rules of quality requirements used in this study.

Table 1 - Available services for composition

Web Service	**Description**
NOAA AVHRR/3 Based Flooded Area Degree Service	Calculates the inundation level of an area based on the evaluation of channel 3A from sensor NOAA/AVHRR3 (ANTUNES; ESQUERDO, 2009)
NOAA AVHRR/3 Based Cloudy Degree Service	Calculates the degree of cloudiness from an area using channels 1, 2, 4 and 5 of sensor NOAA/AVHRR3 (ANTUNES; ESQUERDO, 2009, FRANÇA; CRACKNELL, 1995)
NOAA AVHRR/3 Based Viewing Geometry Fitness Degree Service	Calculates the adequateness of configuration from illumination and look angles from satellite (JACKSON; HUETE, 1991)
NOAA AVHRR/3 DataSet Service	Provides geo-referenced remote sensing data of channels 1, 2, 3A, 3B, 4, 5, solar zenith angle and satellite elevation of sensor NOAA AVHRR/3
NOAA AVHRR/3 Based NDVI Service	Calculus of NDVI from channels 1 and 2 from sensor NOAA AVHRR/3

Table 2 – Quality Indicators

Indicator	Type of Data	Associated Service	Description
FloodedAreaIndicator	Image	NOAA AVHRR/3 Based Flooded Area Degree Service	Indicates percentage of flooded area
CloudyIndicator	Image	NOAA AVHRR/3 Based Cloudy Degree Service	Indicates percentage of cloud coverage
ViewingGeometryFitnessIndicator	Image	NOAA AVHRR/3 Based Viewing Geometry Fitness Degree Service	Indicates quality of sensing related to the geometry of satellite sensing

Table 3 – Services and Rules of requisites of geo-data quality

Service	Restriction
NOAA AVHRR/3 Based NDVI Service	MeetingNDVIRequirements(?geodata, dqronto:True) ← config:MaximumFloodedAreaDegree(config:processo, ?MAXFLOODEDAREADEGREE) ∧ FloodedAreaIndicator(?geodata, ?FLOODEDAREADEGREE) ∧ floatValue(?FLOODEDAREADEGREE, ?floatFLOODEDAREADEGREE) ∧ swrlb:lessThan(?floatFLOODEDAREADEGREE, ?MAXFLOODEDAREADEGREE) ∧ RemotelySensedDataReliability(?geodata, dqronto:True) RemotelySensedDataReliability(?geodata, dqronto:True) ← config:MaximumCloudyDegree(config:processo, ?MAXCLOUDYDEGREE) ∧ config:MinimumViewingGeometryFitnessDegree(config:processo, ?MINVGFDEGREE) ∧ CloudyIndicator(?geodata, ?CLOUDYDEGREE) ∧ floatValue(?CLOUDYDEGREE, ?floatCLOUDYDEGREE) ∧ swrlb:lessThan(?floatCLOUDYDEGREE, ?MAXCLOUDYDEGREE) ∧ ViewingGeometryFitnessIndicator(?geodata, ?VGFDEGREE) ∧ floatValue(?VGFDEGREE, ?floatVGFDEGREE) ∧ swrlb:greaterThan(?floatVGFDEGREE, ?MINVGFDEGREE)

PROTOTYPE

A knowledge base was elaborated containing semantic descriptions about some spatial analysis operations and of services related to the calculus of NDVI. Besides semantic descriptions of services, the knowledge base of the prototype is formed by ontology for geo-data types, ontology of geo-data quality attributes and rules of quality parameters. The ontology and rules were constructed respectively on OWL (McGUINNESS; VAN HARMELEN, 2004) and SWRL by the ontology editor Protégé (STANFORD CENTER FOR BIOMEDICAL INFORMATICS RESEARCH, 2010). The service compositions were generated from this base, using a prototype of mechanism for the composition of geographic services implemented, using the programming language Java and the tool Jena (JENA, 2010) for the development of applications at the semantic Web. The composition mechanism generates a simplified process in WS-BPEL, from the specification of a type of geo-data to be generated.

RESULTS AND DISCUSSION

After the insertion of information needed for the calculus of NDVI at the knowledge base, corresponding to descriptions of services, types of data, quality indicators and rules of quality requirements, the inquiry presented at figure 6 was submitted to the mechanism for the automated generation of service composition. At this specific inquiry, a composition is desired which produces data of NDVI type, considering a parameter for the red spectral band as the channel 1 of sensor NOAA AVHRR/3 and another parameter for the near red spectral band as the channel 2 from the same sensor.

```
type:NDVI
    { attr:NOAA_AVHRR3_CellGeometry, attr:NormalizedDifferenceVegetationIndex }
    <
        type:RedSpectralBandParameter = type:NOAA_AVHRR3_Channel_1
        type:NearInfraRedSpectralBandParameter = type:NOAA_AVHRR3_Channel_2
    >
```

Figure 6 – Specification of goal for composition

Besides the information related to the NDVI, the knowledge base used in this study presents semantic descriptions for other 18 services. The composition mechanism selected the adequate services, generating a plan for the execution of services in WS-BPEL language according to the scheme presented on figure 7. This service composition reflects the knowledge on the Pantanal region, described in scientific papers used for the elaboration of the knowledge base, i.e.:

- Adaption of procedure for the detection of clouds, reflecting the specific needs of the Pantanal region (ANTUNES; ESQUERDO, 2009; FRANÇA; CRACKNELL, 1995);
- Identification of flooded region based on data from channel 3 A of sensor NOAA AVHRR/3 (ANTUNES; ESQUERDO, 2009);
- Quality evaluaton of NDVI calculus, based on the attendance of quality requirements of data described for the service. These requirements are based on external and internal factors to remote sensing (JACKSON; HUETE, 1991).

The services incorporating this knowledge can be reused in other service compositions for the Pantanal region, where the same types of tasks are required.

In this scheme of services, parallel horizontal bars indicate parallel execution (notation of WS-BPEL of tool Eclipse 3.4). In this composition, invocation of quality indicators of services of data for the calculus of NDVI are planned to be executed before this calculation. Information extracted by these services subsidize the quality evaluation of data delivered to the service to calculate the NDVI. A report of the process records the conditions which were not attended. The inclusion of services of properties transformation and of services for the extraction of values from quality indicators is based on the rules of quality requirements and it allows that the service composition obtained is more robust referring to the quality of input data, when compared with compositions generated automatically by other approaches.

So the flow of execution from composition services approaches to the sequence of activities performed by a specialist in spatial analysis. Normally these activities are done interactively with the support of geo-processing tools. The quality of data obtained by a specialist through these tools, depends on his/her knowledge and experience. The proposal presented in this paper can be used by this specialist as a support tool, allowing a more detailed description of services and operations available over one type of data and its application restrictions.

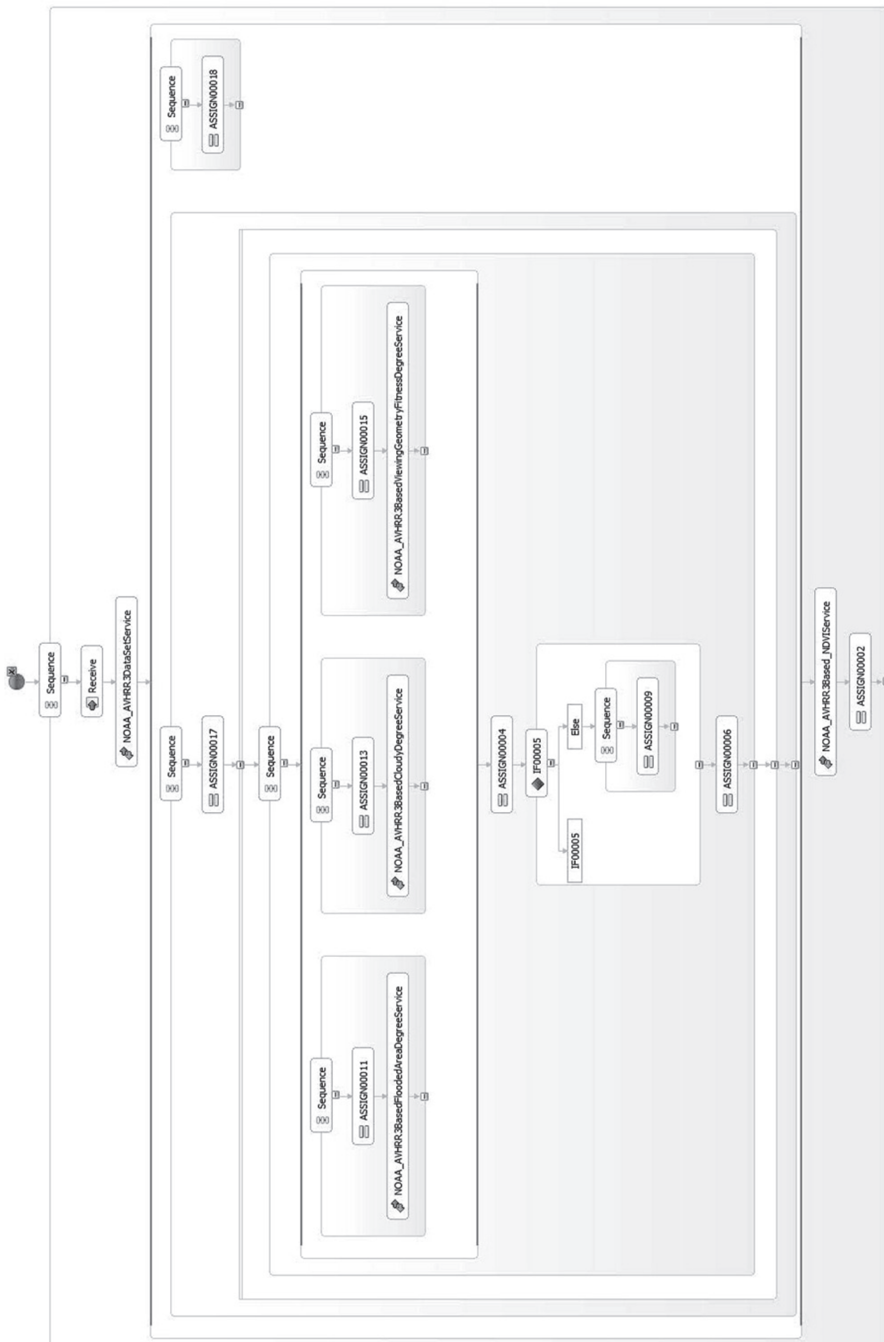


Figure 7 - Service composition for the generation of NDVI calculation

Nevertheless, the automation of the composition process of geographic services presents as advantages the possibility of reuse of previously generated compositions, of repetition of execution from analysis procedures and of systematization of such procedures. Sharing of these procedures and the organization of a knowledge base in accordance with the proposal of this work, allows sharing and standardization of analysis criteria among specialists of a domain.

A more complete knowledge base about the Pantanal can be developed from the more comprehensive analysis of scientific works about this region.

CONCLUSIONS AND SUGGESTIONS

In this work an approach was presented for the automated composition of geographic services and its application in a case study in the Pantanal region. In this study, information about specific aspects from the Pantanal were registered in a knowledge base. This knowledge base, containing service descriptions, type of data and conditions for data use by services, was used for the automated construction of a process for the calculation of the NDVI. These same information can be reused at the construction of other processes, allowing so sharing of this knowledge.

The application of this proposal assumes a definition of a base sharing knowledge within a specific application domain, aiming to obtain results which could be used in real applications.

The adoption of the methodology proposed in this work, in the context of the Pantanal region, permits the organization and cataloging of functionalities, geo-processing and analysis algorithms implemented systematically as Web Services. The use of these services in a simple form or in compositions can be done reliably, since the geo-data quality requirements are available for automatic verification. These requirements can be declared considering specific quality concepts for the Pantanal region, involving climatic, topologic, social, etc. aspects. These requirements allow the selection of services that implement adequate algorithms to these conditions, promoting a more adequate treatment to geo-data from the region, with a consequent improvement on the quality of the results produced.

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