A DEVELOPMENT PROCESS FOR WEB GEOGRAPHIC INFORMATION SYSTEM
A Case of Study

María José Escalona, Arturo Torres-Zenteno, Javier Gutierrez
Department of Computer Languages and Systems, University of Seville, Seville, Spain

Eliane Martins, Ricardo da S. Torres, M. Cecilia C. Baranauskas
Department of Information System, Institute of Computing, State University of Campinas, Campinas, Sao Paulo, Brazil

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Abstract: This paper introduces a process for developing Web GIS (Geographic Information Systems) applications. This process integrates the NDT (Navigational Development Techniques) approach with some of the Organizational Semiotic models. The use of the proposed development process is illustrated for a real application: the construction of the WebMaps system. WebMaps is a Web GIS system whose main goal is to support harvest planning in Brazil.

1 INTRODUCTION

A geographic information system (called GIS from now) is a software system that manages geo-referenced information. GIS systems are an automated system used for storing, analyzing and manipulating geographical information. Geographical information represents objects and actions where geographical location is indispensable information (Aronof, 1989; Bull, 1994). In this context, a Web GIS system offers different GIS services for analysis and visualization of geographical information on the Web (Kim, 2002).

The purpose of this paper is to propose a process for developing Web GIS systems. This process integrates models from Navigational Development Techniques (NDT) methodology (Escalona et al., 2004) with models from the Organizational Semiotic technique (Liu, 2000).

The process proposed in this paper has been applied for developing the WebMaps system. WebMaps is a real Web GIS system whose main goal is to support harvest planning in Brazil (Macário et al., 2007).

This paper is organized as follows. Section 2 introduces preliminary concepts needed to understand the process. Section 3 describes the techniques used in the process. Then, section 4 presents the case study based on WebMaps. Finally, section 5 outlines conclusions and ongoing works.

2 PRELIMINARY CONCEPTS

2.1 Navigational Development Techniques (NDT)

NDT (Escalona et al., 2004) is a methodological process based on the navigation of web and hypermedia systems. NDT defines the Requirements Engineering and Analysis phases of a software development process. In the Requirements Engineering phase, NDT defines four models: information storage requirement model, functional requirements model, actors model, and interaction requirements model. The information storage requirements model specifies the information needs of the system under development. This model answers the following questions: what information must the system store? What information does the system need?

Functional requirements model specifies the operation of the system, this model answers the following question: what can the system do? The

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actors model specifies the roles of actors that interact with the system, their incompatibilities and generalization among them.

The interaction requirements model is a relevant model for a navigational system. The interaction requirement model provides the information and the functionality asked by the user.

In the Analysis phase, NDT defines two models. The conceptual model is a set of conceptual classes. These classes represent the static structure of the system. The navigational model is a class diagram with special classes that offers a view of the conceptual model and shows how to navigate through the information managed by the system

The main documents obtained in NDT are: the System Requirement Document (SRD) in the Requirements Engineering phase and the System Analysis Document (SAD) in the Analysis phase.

2.2 Organizational Semiotics

As a "doctrine of signs", Semiotics covers several disciplines (Liu, 2000). The main goal of the Semiotic is to facilitate the understanding of the way signs are used by people for all purposes. Every organized behavior is affected by the communication and interpretation of the signs by individual or by groups of people. Thus, the Organizational Semiotics studies organizations, by taking advantage of concepts and methods from Semiotics.

Organizational Semiotics offers methods to understand the organizational context. The Methods for Eliciting, Analyzing and Specifying Users' Requirements (MEASUR) (Stamper et al., 1997). MEASUR is a set of methods based on modeling rules and requirements specification that can be used for system development

Some of the methods included in MEASUR are the PAM (Problem Articulation Method), the SAM (Semantic Analysis Method) and the NAM (Norm Analysis Method). The PAM is one of the methods used in this paper. It may be applied in early stages of the development process, when a vague and undefined problem is found. The techniques included in PAM are:

- Stakeholder analysis: This technique performs an analysis of the actors, customers, providers, partners, competitors, users and government.
- Evaluation table: this technique verifies for each stakeholder the main problems at the time of applying those techniques.
- Semiotic framework: This technique specifies characteristics in the level of physic world, empiric world, syntactical world, semantic world, pragmatic world, and social world.
- Collateral analysis: This technique helps during analysis and building of relations among unitary systems, which involve complex systems.

This work also used the SAM method. This method is used for capturing and representing the requirements using a formal and precise model

- Ontology diagram: The ontology diagram defines concepts and terms used in the domain of a particular problem.

Finally, this paper refers to a case study in which we applied an adaptation of the mentioned methods at the Institute of Computing, UNICAMP (Baranauskas et al., 2005). This adaptation is included:

- a description of the context of the problem.
- a description of the functional and non functional requirements.
- an organization of the content: it specifies the structure and organization of the content into the system.

3 DEVELOPMENT PROCESS FOR WEB GEOGRAPHICAL INFORMATION SYSTEMS

In the first activity, the process begins with a Requirement Engineering phase. Next, an Analysis phase is performed. Later, the Abstract Interface model is built. Finally, the target system is implemented.

Figure 1 shows the development process. Shows how models from NDT and from Organizational Semantic are built following this process. The OOHDM (Oriented-Object Hypermedia Design Method) (Rossi, 1996) models are presented in the Fig. in order to reference the classic models. OOHDM is one of the most studied approaches. This approach for web developing is based on Hypermedia Design Model (HDM) (Garzotto et al., 1993) a structured approach to model hypermedia system

Next sections describe in depth the development process for Web GIS systems.

3.1 Requirements Engineering

The main goal of the requirement engineering is to find the real needs of the users. These needs will drive the implementation of the system under development. Recent researches have proved that

many software projects have failed due to errors in requirements elicitation (Boehm). This means that requirements are often incompletes or misunderstood.

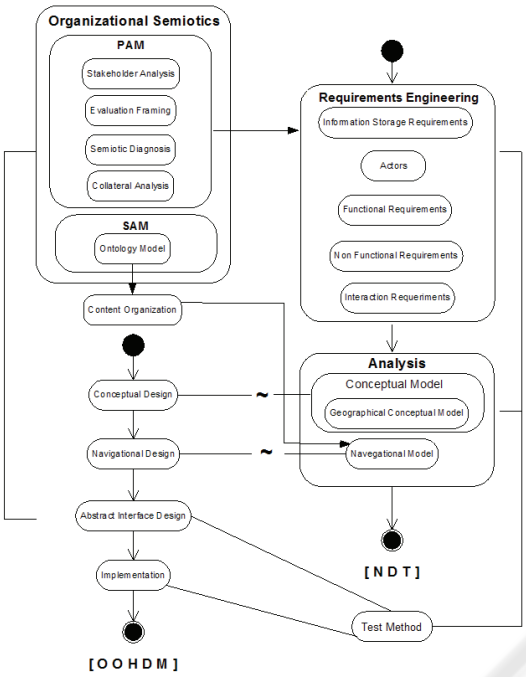

Figure 1: Development process for Web GIS applications (extended).

This process introduces the use of the Organizational Semiotics during the requirement elicitation to solve that problem (Liu, 2000). Organizational Semiotics uses a mature set of techniques present in MEASURE (Stamper, 1997), for the definition of requirements. This phase involves a set of workshops among all interested people. The main objective of the workshops is to find the actors of the system and the functional and non-functional requirements. Social, politic, cultural, and ethics issues of the problem are also considered (Baranauskas et al., 2005).

Once the requirements have been obtained using Organizational Semiotics, NDT methodology (Escalona et al., 2004) is applied for improving requirements. Actor model, information model and interaction model are added to the requirements.

3.2 Analysis

The objective of the analysis phase is to detail, define and validate the requirements. In the NDT methodology, the analysis phase involves the definition of two main models: conceptual model and navigational model. A relational model might be generated from the conceptual model. The relational model is useful for the implementation of the databases of the system under development.

NDT is helpful in the generation of navigational model for the pages that include information processing. However, NDT is not helpful for organizing static information. The Organizational Content approach is, then, used to complement the content and models generated by NDT. The Organization content used has been proposed and adapted from the ontology diagram by the research team at Institute of Computing, Unicamp (Baranauskas et al., 2005).

3.3 Implementation of the Abstract Interface Model

During the system design phase or abstract interface generation phase, the design of the pages is needed. In this phase, the web designer may also use the artifacts from the analysis phase. This means that the web designer should use the final navigational model for implementing user prototypes.

4 CASE STUDY – WEBMAPS

WebMaps is an interdisciplinary project still in development at the Institute of Computing, Unicamp. The main goal of this project is the monitorization and planning of harvests in Brazil. Several experts of different areas of knowledge participate in WebMaps, including: image processing, software engineering, database, geo-processing, eco-environmental, and computer-machine interaction. WebMaps integrates heterogeneous data from several sources. WebMaps also offers several services to manage all those information. This system allows defining a base platform for the designing, implementation and evaluation of integrated policies of harvests planning. The system also allows the execution of queries about the evolution of the harvests for a long time line.

The WebMaps system is able to generate Normalized Difference Vegetation Index (NDVI) curves (CPETC, 2007). A NDVI curve describes the vegetation indexes for the normalized difference for a given region. Those indexes show the amount of vegetation in a concrete time period. Those indexes are obtained by processing satellite images - Moderate Resolution Imaging Spectroradiometer (MODIS) images.

The images are obtained periodically, therefore indexes are always updated. The images cover all the Brazilian territory during a four years period. The images have been obtained from NASA (MODIS, 2007). Every image has a size of 109'6 MB and a new image is obtained every 15 days.

The processing of the satellite images for the generation of NDVI curves is a slow process. Due this reason, a set of masks were generated and applied to the images to reduce the processing time. The architecture is composed of a client layer and a server layer. The server is divided into three modules. All modules have been implemented using Java and C languages. The first module is in charge of supporting user and property registration. The second module supports the queries. Finally, the third module stores the managed data using PostgreSQL database and hard disk files.

JSP pages and C modules are stored in the server side. The goal of C modules is to process the satellite images and to generate the masks used to build the NVDI curves, as mentioned earlier. The curves are generated by taking into account the query defined by the user. The interaction between C and Java code has been implemented using the Java Native Interface (JNI). Benefits of using native code interfaces in the developing of system are exposed in (Czajkowski, 2001).

Next paragraphs describe all the phases of the process introduced in the previous section and show their application in the WebMaps development.

4.1 Requirements Engineering

This phase was initiated with the application of the Organizational Semiotics (Liu, 2000) adapted methods. Several workshops were organized for eliciting requirements. The workshops were conducted by requirements engineers and stakeholders in a cooperative way. Seventeen participants from several knowledge areas worked together in the workshops. The knowledge areas of the participants were: image processing, software engineering, databases, geo-processing, agro-ecologic studies, human-computer interaction, among others. The artifacts of the Organizational Semiotics were used as communication tools among workshops. Reference (Baranauskas et al, 2005) presents in detail the use of the Organizational Semiotic during the workshops.

The requirement engineering phase uses the patterns and models developed by NDT (Escalona et al., 2004) – see Section 2.1. This section only exposes the application of the process and it does not show all patterns

First, NDT patterns drive the identification of the system objectives. The goal of this task is to know the limits of the problem. Some WebMaps objectives are: showing data about a concrete geographical region, working with geo-referential data, and adapting the system according to user profiles.

Once the objectives are identified, NDT proposes to identify the system requirements. One of the system requirements are the information requirements. Those requirements define the information that the system must store. Once information requirements are specified, the actors who will interact with the system must be identified. Every actor is related to an interaction role. In the WebMaps system, there are for different user categories: non registered, registered, coordinator, and member of equipment.

After the specification of the actors, the incompatibilities among those actors are analyzed. The definition of incompatibility is basic, due every incompatibility may define different interface of the other interfaces generated for the other actors. The data that will be stored into the system and the users that may manage those data have been defined in the previous activities. However, it is also needed to know which operations may be performed with the stored information and which functionalities and services may be offer to the users.

NDT proposes two diagrams for capturing and defining the functional needs of the system under test. The first diagram is the use cases diagram (Baranauskas et al, 2005). The second one is the textual information diagram. This diagram is specified using patterns to define the meanings of the information.

The use case model of WebMaps was generated from the artefact obtained in the activities performed in the workshops and, mainly, from the application of the Organizational Semiotic. Use cases also show the interaction of the different actors with the system.

At this time, the information that the system will store and the actors that will interact with the system and the functionality of the system are known and formally defined. However, this is not enough for navigational systems. The system must also offer information and functionality at the right moment. Furthermore, it defines the most adequate presentation strategy. The order of information is a relevant aspect. Those requirements are stored in interaction requirements. NDT defines the

interaction requirements with two patterns: recover criteria (or phrases) and visualization prototypes.

Visualization prototypes are defined after the definition of the phrases. Visualization prototypes allow specifying expected navigation process into the system.

Once requirements are identified, they must be validated. The construction of a traceability matrix is a value technique which allows validating the results obtained from the requirement phase.

The requirement engineering phase ends at this time. The document of system requirement (SRD) is the final artefact obtained.

4.2 Analysis

The goal of the analysis phase is the definition of the analysis models: the conceptual and the navigational model. The conceptual model represents the static structure of the system, while the navigational model represents its navigational structure. NDT describes a systematic process that allows generating both models from the artefacts obtained in requirement engineering phase.

The conceptual model is composed of a single diagram. This diagram is represented by two elements: the conceptual classes diagram and the information dictionary. The conceptual classes diagram uses the notation proposed by UML. The information dictionary describes, in a textual way, the meaning of classes and associations from the conceptual class diagram.

Once the static structure of the system has been created, the navigational model is defined. The navigational model represents how to navigate through the conceptual information. This model is a view of the conceptual model. It represents the elements of the navigation and their relations. The navigational model may be quite different depending on the roles of the user logged into the system. As mentioned before, NDT proposes a set of process to generate this model systematically.

NDT describes the elements of a navigational model using patterns, in the same way that models used in the previous phases. After the definition of the basic navigation model, a revision of the model is needed. In the case study, we found out that the navigation model generated involves the dynamic information navigation as well as information that need to be processed by the server. However, it was detected the lack of a navigational model for the static content. The Organizational Semiotics offers an artefact to solve this limitation. Figure 2 shows the relation between the ontology model with the system content. Those models were generated by the human-machine interface engineers of WebMaps (Baranauskas et al., 2005).

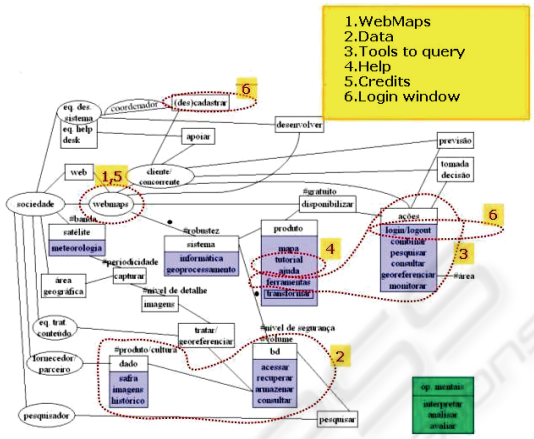

Figure 2: Ontology model (Baranauskas et al, 2005).

The ontology model presents a context that involves concepts and terms used in the problem domain. A more complete description about the generation of those models can be found in Baranauskas et al, 2005. Main menus of the system are generated from the product obtained after the application of Organizational Semiotics adapted methods. Now, it is possible to build the final navigational mode, shown in Figure 3. The basic navigational model is associated with the main menus of the system.

4.3 Abstract Interface Model and Implementation

In this phase, a web designer collaborated with the WebMaps team. The web designer built the abstract interfaces. The language used was Java.

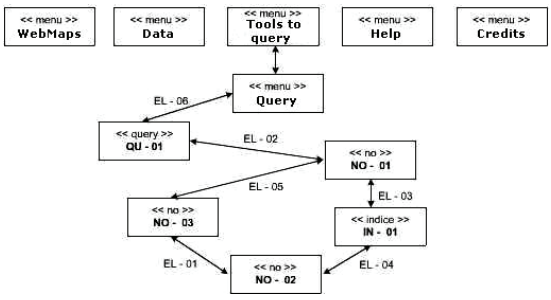

Figure 3: Final navigational model.

As WebMaps is a Web GIS system, it needs large data processing. Reference (Torres-Zenteno et

al., 2006) presents the functional testing of WebMaps. The goal of the test process was to determine if the behaviour of the system is similar to that one indicated by the functional requirements.

5 CONCLUSIONS

This paper has presented a development process model focused on Web GIS applications. The model integrated artifacts from NDT and artifacts from the Organizational Semiotic. This process was applied to a real system called WebMaps. This system is a Web GIS application, which main goal is to support harvest planning in Brazil.

After the application of the process, a functional prototype of WebMaps was obtained.

The system requirements document and analysis document were created following the indications of the process. Both documents were not included in this paper due space limitations. However, this paper has shown examples of the most relevant models to improve the understanding of the process.

We are currently defining the conceptual model of the geographic data. We plan to add this model in the proposed development process.

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