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SIGAPP FY’15 Quarterly Report

April 2015 – June 2015
Sung Shin

Mission

To further the interests of the computing professionals engaged in the development of new computing applications and to transfer the capabilities of computing technology to new problem domains.

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A Message from the Editor

Welcome to the summer issue of Applied Computing Review! First of all, I am so grateful that the 30th annual ACM SAC (Symposium on Applied Computing) was successfully held in Salamanca, a UNESCO declared world heritage city, Spain. Almost 500 researchers and practitioners around the world gathered together, and I would like to take this opportunity to thank all the attendees as well as committee members and sponsors who made significant efforts and endless dedication.

This issue of ACR includes four selected papers presented at the SAC conference. All the selected papers have been revised and expanded for inclusion in ACR, and I can proudly tell you that each and every single one of them is excellent. I want to express my special gratitude to the editorial board members who have performed technical paper reviews and to the authors for contributing the modern techniques in their research area.

Our goal of ACR is to provide you with a platform for sharing innovative ideas among professionals in various fields of applied computing. Lastly, please be advised that the 31st ACM SAC will be held in Pisa, Italy next year. I hope many of you to join and make the next conference another success. Your continuous support and cooperation will be very much appreciated. Have a terrific summer!

Sincerely,

Sung Shin
Editor in Chief & Chair of ACM SIGAPP

ACM SIGIR 2015

SIGIR (Special Interest Group on Information Retrieval) provides a forum for the presentation and demonstration of new research results and development in the field of information retrieval. The 38th SIGIR will feature 5 days of papers, posters, tutorials and workshops starting on August 9th. Details about the conference can be found at http://sigir2015.org/.

Next Issue

The planned release for the next issue of ACR is September 2015.
SAC 2015 Report

The 30th Annual meeting of the ACM Symposium on Applied Computing (SAC) was held in Salamanca, Spain, April 13 to 17, 2015. The conference was hosted by the University of Salamanca. This year, the conference attracted over 470 attendees including local host committee and graduate students from the host Institution. The event was a great success with over 97% attendance rate. This is due to the exceptional dedication of the local organizing committee and the generous support the conference received from local sponsors - Telefonica and IBM. The Steering Committee extends its thanks and gratitude to the local host and sponsors for their generous contributions and support. This year, the conference featured technical sessions, tutorials, keynote sessions, posters, industrial panels, and Student Research Competition program.

The Call for Papers attracted 1211 submissions from 57 countries. All submitted papers underwent the blind review process and 291 papers were finally accepted as full papers for inclusion in the conference proceedings and presentation during the Symposium. The final acceptance rate for SAC 2015 is 24% among all tracks. In addition, 77 papers that received high review scores were invited as short papers for presentation during the Posters Program. The four-day Technical Program consisted of two keynote sessions and research presentations from all 37 tracks covering a wide range of topics on applied computing and emerging technologies. For more details please visit http://www.acm.org/conferences/sac/sac2015/.

The Call for Student Research Abstracts, for participation in the Student Research Competition (SRC) Program, attracted 40 submissions, of which 20 submissions were invited for participation in the program. The SRC program is sponsored by Microsoft Research. Invited students participated in poster display and oral presentations. A committee of five judges evaluated the posters and selected five winners for the second round (oral presentations). The judges then selected top three winners from the oral presentations round. The winners were recognized during SAC Banquet and presented with award medals and cash prizes. The winners of SAC 2015 SRC Program are below, and the first place winner will advance to the SRC Grand Finals.

First Place: From Context to Query
Jörg Schlöterer, University of Passau, Germany

Second Place: Multi-Document Text Summarization for Competitor Intelligence: A Methodology Based on Topic Identification and Artificial Bee Colony Optimization
Swapnajit Chakraborti, Indian Institute of Management Indore, India

Third Place: Multi-Criteria Based Vertical Handover Decision in Heterogeneous Wireless Network
Murad Khan, Kyungpook National University, South Korea

The Tutorials program featured 6 invited tutorial presentations. The tutorials covered a variety of topics and attracted over 100 attendees. The Call for Track Proposals resulted in accepting 37 tracks. The selections were made based on the success of those Tracks in the previous editions of SAC as well as targeting new and emerging areas in applied computing. The Tracks were organized into five different themes: AI & Agents, Distributed Systems, Information Systems, Software Development, and System Software & Security. The conference proceedings and the technical presentations were focused around these themes to form a series of related track sessions.

The success of SAC 2015 was made possible through the hard work of many people from the scientific community who had volunteered and committed many hours to make it a successful event, especially, the Track
Chairs and their Program Committees. On behalf of the Organizing and Steering Committees, we congratulate all of the authors for their successful work. We also wish to thank all of those who made this year's technical program a successful one, including the speakers, track chairs, reviewers, program committee members, session chairs, presenters, and attendees.

The preparation for SAC 2016 (http://www.acm.org/conferences/sac/sac2016/) is underway. The conference will be held in the historic city of Pisa, Italy. The conference is hosted by the University of Pisa and Scuola Superiore Sant'Anna University. We welcome your submission to SAC 2016 and hope to see you in Pisa next year.

Best Regards to all,

[Signature]

Hisham Haddad
Member of SAC Organizing and Steering Committees
A Formal Method for Modeling Deployment Architectures Based on Bigraphs

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ABSTRACT
Software deployment is executed according a deployment architecture which describes the allocation of software components to its hardware hosts. In this paper, we tackle the issue of constructing correct deployment architectures for large distributed systems. Actually, such architectures should satisfy various constraints related to the software components and the target environment such as the hierarchical description of components, their connections and the resource constraints. We present a formal method for constructing deployment architectures using a formal language called BRS (Bigraphical Reactive System). This method provides a correct by design approach based on multi-scale modeling ensuring the correctness of the obtained deployment architectures. Following our approach, the designer starts by modeling the first scale architecture which is refined automatically by successively adding smaller scale components until obtaining the last scale deployment architecture.1

1. INTRODUCTION
Software deployment represents a sequence of related activities for placing a developed application into its target environment and making the application ready for use. For component-based applications, OMG Deployment & Configuration Specification (OMG D&C Specification) [15] outlines the following activities: installation which involves populating a repository with the application components; configuring the functionality of the installed application in the repository; planning which generates a deployment plan (i.e., describes a correct deployment architecture); preparing the target environment by moving the application components from the repository to the specified hosts; and launching the application.

For large distributed systems, finding a correct deployment architecture is considered as a challenging task. Actually, a correct deployment architecture should respect a set of constraints related to both software components and target environment such as the hierarchy of components, their connections and their resource constraints. Satisfying these constraints make the modeling of deployment architectures more difficult.

In the literature, there are several research activities dealing with software deployment. But most of them are based on informal model and lack a solid mathematic foundation to ensure the correctness of deployment architectures. They have focused on satisfying only the resource constraints. Whereas, in our work, we propose a rigourous solution based on a formal model called BRS (Bigraphical Reactive Sys-
The execution model and configurations, the target model, and the component model specification [15]. This specification offers three models. To address the issues of software deployment, these methods in-clude the use of OMG Deployment and Configuration (D&C) speci-fication, which respects the defined constraint, ensuring, in this way, the correctness of the obtained architectures. After constructing the architectures of both software architecture model and execution environment model, we apply the relation between the two models (i.e., integration model) in order to obtain deployment architectures.

The rest of this paper is organized as follows. In section 2, research activities dealing with software deployment are presented and in section 3, we present an overview of bigraphs. In section 4, we explain our bigraphical based approach for the deployment modeling. In section 5, we consider communicating systems as a study field. Then, we introduce in section 6 a case study called “Smart Home” to apply our approach and its simulation with the BPL Tool in section 7. Finally, section 8 concludes this paper and gives some directions for future work.

2. RELATED WORK

Various research studies have proposed methods to address the issues of software deployment. These methods include the use of OMG Deployment and Configuration (D&C) specification [15]. This specification offers three models. The component model defines descriptors for components and configurations, the target model defines descriptors for the target site on which applications can be deployed and the execution model defines the Deployment Plan, which describes deployment decisions. It defines an Execution Manager which executes application according to this plan.

We have identified some frameworks which have been developed on top of this specification like DAnCE [4], Dacar [5] and Deployment Factory [8]. DAnCE is a QoS-enabled Component Deployment and Configuration Engine targeted for DRE systems. This framework deals only with CORBA Component Model. Whereas Deployment Factory is an unified environment for deploying component based applications. It proposes a generic component model which is an extension to the OMG D&C specification. These frameworks do not provide mechanisms for redeployment and dynamic reconfiguration. However, Dacar is a model-based framework for deploying autonomic software distributed systems. It is based on a control loop and Event-Condition-Action (ECA) rules. The main limitation of these research activities is the manual deployment planning. The designer should assign the software components to the hardware ones which is a hard task especially with large scale systems.

Other research activities have proposed architecture-based approaches using ADL (Architecture Description Language) [9, 11] and graphs [7, 17, 3]. Hoareau et al [9] present a support for deploying and executing an application built with hierarchical components. It presents an ADL extension for specifying a context-aware deployment. This deployment is performed in a propagative way and is driven by constraints put on the resources of the target hosts. The framework presented in the work of Malek et al [11] aims at finding the most appropriate deployment architecture for a distributed software system with respect to multiple QoS dimensions. The framework supports formal modeling of the problem that provides a set of algorithms for finding the optimal deployment. Heydarnoori et al [7] propose a graph based deployment planning approach for maximizing the reliability of component-based applications. They demonstrate that this deployment problem corresponds to the multiazy cut problem in graph theory. Also, the work of Zhang et al [17] defines a component graph to represent component-based distributed applications and a tree network topology to describe the runtime environment. It defines the resource cost objective function and formulates component deployment optimization problem as mathematical programming problem.

Other research activities like [1, 12] have proposed a dedicated language (Domain Specific Language) for deployment. Dearle and Kirby [1] propose a framework for autonomic management deployment and configuration of component-based distributed applications. An initial deployment goal is specified using Deladas (DEclarative LAnguage for De-scribing Autonomic Systems). A constraint solver is used to find a configuration that satisfies the goal, and the configuration is deployed automatically. If, during execution, the goal is no longer being met, a full restart of the deployment process is performed. Matougui et al [12] propose the j-ASD middleware that addresses the autonomic deployment of ubiquitous systems. This middleware provides a DSL specifying deployment constraints. This specification is compiled into a constraint satisfaction problem, which is resolved automatically by a constraint solver. The generated deployment plan is dynamically executed by a mobile agent system.

We can note that the research activities [9, 11, 7, 17, 1, 12] deal only with resource constraints during the construction of the deployment architecture. They do not take into account the respect of structural constraints to validate the deployment architecture. Whereas, in our work, we deal with both structural and resource constraints.

2.1 Problem statement

The efficiency of software systems relies on the correctness of their deployment. Actually, a deployment architecture must satisfy a set of constraints related to both software architecture (i.e, hierarchy of components and their connectivity) and target environment (i.e, structural constraints and resource constraints). Indeed, for large distributed systems with many requirements and constraints, it is hard to construct a correct deployment architecture that satisfies both
"X-node", which means a node that has been assigned a different nodes (for example, Control: Each node in the bigraph is assigned a control.

Interfaces: Bigraphs can be built through their inter- faces. We distinguish two types of interfaces: inner interface and outer interface. The inner interface is defined by I= \{x_0, v_1, v_2\} (cf. Figure 2) and inner names like x_0, y_1, y_2 (cf. Figure 2) are joined by e_1 in Figure 1). A bigraph combines two graphical structures - a place graph and a link graph based on the same node set, hence the term bigraph.

Place graph: It is a hierarchical tree that describes the locality of the nodes. In this graph, trees are rooted by regions represented by dashed rectangles (cf. Figure 2). There can also be sites, represented as grey rectangles. A site is a hole that can host new nodes.

Link graph: It is an hypergraph that describes the connectivity of nodes. Within this graph, there can be outer names like y_0, y_1, y_2 (cf. Figure 2) and inner names like x_0, x_1 (cf. Figure 2) represented as open links. These names define the connection points at which coincident names may be fused to form a single link.

Figure 1. A Bigraph G

Figure 2. place and link graphs

Figure 3. A reaction rule

J=\langle n, Y \rangle \text{ where } n \text{ is the number of regions and } Y \text{ is the set of outer names. In a conventional manner, the inner names are drawn below the bigraph and the outer names above it. In this example, } I=\langle 2, \{x_0, x_1\} \rangle \text{ and } J=\langle 2, \{y_0, y_1, y_2\} \rangle.

3.2 Bigraphical Reactive System

A BRS (Bigraphical Reactive System) is a set of bigraphs and a set of reaction rules that may be applied to rewrite these bigraphs. Each reaction rule consists of two bigraphs: a Redex \$R\$ and a Reactum \$R'\$. The application of the rule consists of identifying the image of \$R\$ in a bigraph and replacing it by the corresponding \$R'\$. For example in Figure 3, the rule allows an Agent-node to enter a Building-node which is placed in the same region. The site (grey rectangle) in the Redex represents all other possible occupants of the Building-node which are unchanged after applying this rule. The graphical representation used above is handy for modeling, but unwieldy for reasoning. Fortunately, bigraphs have an associated term language [2]. The corresponding algebraic expression (using details in table 1) of this rule is: \$\text{Agent}_{x,y}[^{\text{Building}}] \rightarrow \text{Building} \cdot \text{Agent}_{x,y}[{^{\text{Building}}}]\$

Table 1. The term language for Bigraphs

<table>
<thead>
<tr>
<th>Algebraic expression</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td>V</td>
</tr>
<tr>
<td>U</td>
<td>V</td>
</tr>
<tr>
<td>U,V</td>
<td>Nesting (U contains V)</td>
</tr>
<tr>
<td>K_x</td>
<td>K-node linked to an outer name x</td>
</tr>
<tr>
<td>d_i</td>
<td>Site numbered i</td>
</tr>
<tr>
<td>/x/U</td>
<td>U with outer name x replaced by an edge</td>
</tr>
</tbody>
</table>

4. THE PROPOSED APPROACH

In order to construct a deployment architecture, we need to describe the software architecture, the execution environment and the relation between them. Based on this issue, we propose an approach for deployment modeling of distributed systems which defines three models:

- **Software architecture model**: This model describes software components, their properties and their architecture (i.e., hierarchy of components and connections between them).

- **Execution environment model**: This model describes the runtime environment including physical nodes, hosts, devices, etc as well as their resource constraints and their architecture.
• **Integration model**: To obtain a deployment architecture, we should define the relation between the two models to map software components on physical ones.

The key objective of our work is to automate the construction of a correct deployment architecture that respects the defined models. For this, we have proposed a formal method which is based on a formal language to guarantee the correctness of the deployment architecture. This formal language should be able to describe both software and physical components. It should emphasize both hierarchy and connectivity of components. It should also provide information on both static and dynamic aspect of the system since we intend to deal with autonomic systems in future work. We have noticed that BRS is the most appropriate language that supports these requirements.

Furthermore, our formal method provides three steps to be followed as highlighted in Figure 4:

- **Step 1: Description** In this step, the designer describes the necessary information like software and hardware components, their properties and their resource constraints. Each component is represented with Bigraph as a node type annotated with attributes to indicate properties or available resources. The designer describes also the structural constraints through conditions on the hierarchy and the connectivity of nodes.

- **Step 2: Generation** In this step, the generation of the deployment architecture is performed automatically following a multiscale modeling approach. In fact, for each model (i.e., environment execution model and software architecture model), a large scale is defined by the designer. Then, it is refined by successively adding smaller scale details until reaching the last scale. Hence, we obtain the set of possible deployment architectures by linking the two models(cf. Figure 4).

The refinement process is performed by applying specific rules. Since we aim to facilitate the modeling task for the designer, we have proposed the concept of meta-rule to describe the transition between scales. Thus, the designer identifies the corresponding meta-rule which will be instantiated automatically according to the specification in order to have the necessary rules for scale transitions. With BRS, a meta-rule is a meta-reaction rule that contains nodes having a variable control (i.e., a variable can represent any control). For example the meta-rule defined in Figure 5 allows to nest a node in another one. This meta-rule is instantiated to have two rules with the controls Building, Computer and Agent. The first one allows to nest a computer-node in a building-node and the second one allows to nest an agent-node in a building-node.

- **Step 3: Selection** In our ongoing work, a deployment architecture is selected from those generated in the previous step according to resource constraints. Hence, we obtain a deployment architecture that respects both structural and resource constraints.

- **Step 4: Execution** After selecting the adequate deployment architecture, it is deployed effectively using a deployment service. To do this, we intend to use the deployment service of the FACUS framework [16]. This service takes as input a deployment descriptor (i.e., an XML file) and executes its by placing software components into correspondent hosts.

5. **MULTI-SCALE MODELING FOR COMMUNICATING SYSTEMS**

In our work, we have addressed communicating systems. These systems are formed by Communicating groups. Each group is composed of devices which share common interest.

Since we aim to facilitate the modeling task to the designer, we have defined, for these systems, the scales of each model and we have defined the necessary meta-rules to be applied for the transitions between these scales and for the integration model.

5.1 **The execution environment model**

This model is represented by the following scales and transitions (we use the notation “scale i” where i is the scale number):

- **Scale i**: such $i \in [0, n]$ where n corresponds to the depth of nesting in a bigraph. For $i = 0$, we obtain the first scale.

- **Transition from scale i to scale i + 1**: The transition to the scale $i + 1$ is obtained by applying a meta-reaction rule allowing to nest a node depicted in Figure 5. The corresponding algebraic expression of this rule is:

  $\text{Nest a node}: X.d_0 \rightarrow X.(Y|d_0)$

  This rule enables to nest a node. So, the transition between two scales leads to increment by 1 the depth of nesting. Therefore, this meta-rule can be applied several times in order to add many nodes residing in the same node.

- **Scale i + 1**: such $i \in [0, n]$. With i=n, we obtain the scale n that represents all physical entities and their
A transition from scale architecture model and the execution environment model is necessary components, three scales and transitions between components. Hence, we have identified for this model the communication like senders, receivers and communication middleware model includes the entities that take part in the communication group (i.e., having the same outer name).

Scale n + 1: This is the last scale of the execution environment model. It represents all the physical entities and their communication.

5.2 The integration model

We propose that the relation between the software architecture model and the execution environment model is a transition from scale n + 1 of the execution environment model to scale 0 of the software architecture model. The latter includes sender and receiver components. In fact, each communication group is ensured by a set of senders and receivers. We consider that communication is done in pull mode (i.e., response to a request). So, an entity belonging a communication group is ensured by a set of senders and receivers.

To ensure this transition, we define the following meta-rule:

Add a sender and a receiver: \( Y_x \rightarrow Y_x.(Sr.x)Rc.x \)

We nest in each node having an outer name \( x \), a sender (Sr-node) and a receiver (Rc-node), then we nest in both of them an \( x \)-node that mark their communication group.

5.3 The software architecture model

For communicating systems, the software architecture model includes the entities that take part in the communication like senders, receivers and communication middleware components. Hence, we have identified for this model the necessary components, three scales and transitions between them by defining corresponding meta-rules (cf. Figure 6).

- Scale 0: represents sender and receiver components.
- Scale 1: provides the middleware components that ensure the communication between the application components. Here, we use the Event-Based Communications (EBC) [13]. EBC is a communication model which provides three types of EBC entities: event producers (EP), event consumers (EC) and channel managers (CM). The EP and EC can be connected to CM, but they can not be directly interconnected. The EP can send data to the CM to which they are connected. The CM returns a copy of the received data to all the EC connected to it. This scale is obtained by nesting an EP-node in each sender, an EC-node in each receiver and a CM-node for each communication group in a node that belongs to this group.

- Transition from scale 0 to scale 1: This transition is performed by applying a set of meta-reaction rules defined by the algebraic expressions given below:
  - Add an EP: \( Sr.x \rightarrow Sr.EP.x \)
  - Add an EC: \( Rc.x \rightarrow Rc.EC.x \)
  - Add a CM: \( /x X_1 \ldots X_n \rightarrow /x X_1 \ldots X_n/CM.x \)

For the third rule (Add a CM), \( n \) is the number of nodes belong a communication group. It will be instantiated for each communication group.

- Scale 2: This is the last scale of the software architecture model. It consists at enriching the link graph by adding new edges that link EBC components.

- Transition from scale 1 to scale 2: Reaching the scale 2 is obtained by applying a set of meta-reaction rules given below:
  - Link EP to CM: \( EP.x||CM.x \rightarrow /y EP_y||CM_y.x \)
  - Link EC to CM: \( EC.x||CM.x \rightarrow /y EC_y||CM_y.x \)

6. CASE STUDY: SMART HOME

In order to apply our approach, we consider a case study named “Smart Home” denoted in the Figure 7. Each room in a smart home can be equipped with heterogeneous devices (sensors like thermometer, presence sensor, light sensor, etc and actuators like air conditioner, lamp, etc). These devices are connected to a home gateway that manages their communication to ensure an intelligent home control like lighting control and temperature control. Sensors record information such as rooms lighting, human presence, temperature, etc. The home gateway receives these information and analyses them in order to configure the devices.

<p>| Table 2. The bigraph node controls of Smart Home |</p>
<table>
<thead>
<tr>
<th>Control</th>
<th>Meaning</th>
<th>Arity</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>Home</td>
<td>0</td>
</tr>
<tr>
<td>R</td>
<td>Room</td>
<td>0</td>
</tr>
<tr>
<td>HG</td>
<td>Home gateway</td>
<td>2</td>
</tr>
<tr>
<td>D</td>
<td>Device: sensor or actuator</td>
<td>1</td>
</tr>
</tbody>
</table>
6.1 The execution environment model

For the smart home, the execution environment model represents home, rooms, home gateway and devices. It includes the following scales:

- **Scale 0**: The designer identifies the node controls as given in Table 2. Then, he models this scale using a bigraph. For the smart Home, this bigraph contains one H-node that represents a Home (cf. Figure 8).

- **Transition from scale 0 to scale 1 (adding Rooms and Home Gateway)**: The transition to the scale 1 is obtained by instantiating the meta-rule for nesting a node. So, the rule is: \( H.d_0 \rightarrow H.(R|d_0) \).

This rule enables to add a Room (R-node) in a Home. We apply this rule as many times as the number of rooms in the home. This number is given by the designer. Here, we have 3 rooms.

The meta-rule for nesting a node is instantiated again to add a Home Gateway. The rule is: \( H.d_0 \rightarrow H.(HG|d_0) \)

- **Scale 1**: This scale presents a home, three rooms and a home gateway. Its bigraph is depicted in Figure 8.

- **Transition from scale 1 to scale 2 (adding Devices)**: The transition to the scale 2 is obtained by instantiating the meta-rule for nesting a node. So, the rule is: \( R.d_0 \rightarrow R.(D|d_0) \).

This rule enables to add a device (D-node) in a room. We apply this rule as many times as the number of devices in the room. Here, we have 5 devices.

- **Scale 2**: In this scale, we obtain the bigraph specifying the home, the home gateway and the 3 rooms. One of these rooms contains 5 devices. This bigraph is depicted in Figure 8.

- **Transition from scale 2 to scale 3 (connecting entities within groups)**: The transition to scale 3 is obtained by applying the closure operation on the bigraph of the scale 2: \( \lfloor gt \rfloor gl \circ scale2 \)

This closure operation enables to link lighting communication group (i.e., links the Home Gateway with the three devices having an outer name \( gt \): presence sensor, light sensor and lamp). It enables also to link temperature communication group (i.e., links the Home Gateway with the two other devices having an outer name \( gt \): thermometer and air conditioner).

- **Scale 3**: The scale bigraph is defined in the last part of Figure 8.

6.2 The integration model

The transition from scale \( n \) of the execution environment model to scale 0 the software architecture model is obtained by instantiating the meta-rule for adding a sender and a receiver for devices within the temperature communication group and devices within lighting communication group. For sake of shortness, we present the instantiated rules for temperature communication group: \( D_{gt}.d_0 \rightarrow D_{gt}.(Sr|gT|Rec|gT|d_0) \)

This rule enables to add a sender (Sr-node) and a receiver (Rc-node) in a device (D-node). The gT-node nested in a sender or a receiver denotes the temperature communication group. We instantiate the meta-rule again to add senders and receivers in the home gateway.

So the rule is: \( HG_{gt}.d_0 \rightarrow HG_{gt}.(Sr.gT|Rc.gT|d_0) \)

6.3 The software architecture model

This model represents senders, receivers and EBC components.

- **Scale 0**: This scale represents the execution environment model including sender and receiver components.

- **Transition from scale 0 to scale 1 (adding EBC components)**: The transition to the scale 1 is obtained by instantiating the three meta-rules of adding EP, adding EC and adding CM. So, the instantiated rules for the temperature communication group are: \( Sr.gT \rightarrow Sr.EP.gT \)

\( Rec.gT \rightarrow Rec.Ec.gT \)

\( /gt D_{gt}||HG_{gt} \rightarrow /gt D_{gt}||(D_{gt}.(CM.gT)||HG_{gt} \)

- **Scale 1**: At this scale, we have the execution environment model (home, home gateway, rooms and devices) with senders, receivers and EBC components. The bigraph at this scale is like the bigraph at the scale 2 depicted in Figure 9 but without the colored hyper-edges. In this scale, we can obtain many Bigraphs due to the choice of the channel manager placement (i.e., the CM-node is deployed on one node belongs to the communication group).

- **Transition from scale 1 to scale 2 (connecting EBC components)**: The transition to the scale 2 is obtained by instantiating the two meta-rules of linking an EP to a CM and linking an EC to a CM:
### 7. VALIDATION WITH BPL

In order to verify the feasibility of the case study, we model our BRS using the BPL Tool (Bigraphical Programming Languages) [10]. BPL is a tool for experimenting with bigraphical models. It provides manipulation and simulation of BRS. It relies on an SML (Standard ML) compiler with an interactive mode to provide a command line interface. The language used in the BPL Tool is called BPLL (BPL Language), and it consists of a number of SML constructs which allows to write BPLL directly in SML programs.

#### 7.1 Execution environment model implementation

For the implementation of our case study, we create a SML file to define the BRS for the execution environment model. Listing 1 presents a portion of this file. In this listing we define:

- The signature of the system denoted in lines 2-5. It is the set of nodes controls (H representing the Home, R representing a Room, D representing a Device and HG representing the Home Gateway).

- The rules denoted in lines 6-14 (i.e., rule for adding a room, adding a home gateway, adding a device). For the sake of shortness, we present in listing 1 only some rules implementation.

- The tactics for prescribing the sequence in which reaction rules should be applied (lines 15-19 of listing 1). According to these tactics, we apply the rule for adding a room three times, then the rule for adding a home gateway, then the rule for adding a device two times for the temperature communication group and finally the tactics for adding EBC components and rules for connecting EBC components within communication groups.

After running the simulation, we obtain the expression of each scale in BPLL. Listing 2 represents the expression of the bigraph obtained at scale 3 depicted in Figure 8. It contains the home, the rooms, the home gateway and connected devices within communication groups.

#### 7.2 Software architecture model implementation

To implement the software architecture model, we complete the SML file with the nodes controls (i.e., Sr representing a Sender, Rc representing a Receiver, EC representing an Event Consumer, EP representing an Event Producer and CM representing a Channel Manager), the rules and their tactics (i.e., rules for adding senders and receivers, rules for adding EBC components and rules for connecting EBC components within communication groups).

After running the simulation of the software architecture model implementation, we obtain the expression of its scales in BPLL. Listing 3 denotes the bigraph obtained at scale 2 in which EBC components are connected. It corresponds to the bigraph depicted in Figure 9.
8. CONCLUSION AND FUTURE WORK

In this paper, we have focused on one of the challenging tasks of software deployment which consists in the construction of a correct deployment architecture. To tackle this issue, we have proposed a formal method based on bigraphical reactive systems. This formal language allows to guarantee a correct by construction architectures. This method provides three steps. At the first step, the designer describes the necessary information for the execution environment model, the software architecture model and the integration model. Then, the second step consists in generating automatically all the correct deployment architectures following a multi-scale modeling approach. In fact, for each model, a large scale is defined by the designer. Then, it is refined by successively adding smaller scale details. This refinement process is performed by applying specific rules. Finally, the third step is the selection of the efficient deployment architecture according to resource constraints. In our work, we have addressed communicating systems. For these systems, we have identified some information in order to ease the task for the designer in the description step. In fact, we have defined the component types for the software architecture model, the scales of each model and the transition between them and also the integration model. Finally, in order to illustrate our approach, we have presented a case study called Smart Home and its implementation using BPL Tool. In future work, we aim to focus on the third step of our approach (i.e., selecting the efficient deployment architecture according to resource constraints). Then we intend to deal with autonomic systems by planning redeployment actions.

9. REFERENCES

ABOUT THE AUTHORS:

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Investigating Accessibility on Web-based Maps

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ABSTRACT
This paper presents results of an accessibility evaluation carried out with web-based map applications. Three points of view were considered: experts on accessibility, evaluation tools and final users (partially or totally blind people). The document WCAG 2.0 (Web Content Accessibility Guidelines) provided us with guidelines for evaluation and GQM (Goal, Question and Metric) approach was used to define and set measurable goals. A number of problems was identified and none of the evaluated applications entirely meet the analyzed criteria. ¹

Categories and Subject Descriptors
D.2.0 [Software Engineering]: General – Standards.

General Terms
Design.

Keywords

1. INTRODUCTION
According to W3C (World Wide Web Consortium) [1], web accessibility is related to the fact that people with different degrees of ability or disability can perceive, understand, navigate and interact with the web. Web accessibility promotes integration and social inclusion for disabled people, providing the use and development of computational tools through pre-established guidelines. Considering the large number of people who have some degree of disability worldwide, W3C, along with their initiative for web accessibility WAI (Accessibility Initiative) created WCAG (Web Content Accessibility Guidelines), which is a set of guidelines that support the development of accessible web content, aiming to support the social inclusion of people with disabilities [2].

There are several initiatives involving the development and research in the domain of web-based maps for blind people [3, 4, 5, 6]. Sound components, tactile maps and haptic technologies are being integrated with navigation systems in order to help the visually impaired. However, we did not find in the literature works about accessibility evaluations in this domain. Therefore, this paper aims to contribute in this area, since evaluations are essential to detect problems and possible improvements to be implemented. Our main objective is evaluating web accessibility on the maps domain based on different points of view.

This paper is organized as follows. Section 2 discusses related work; Section 3 presents the evaluations performed, the methods utilized and their findings and Section 4 presents Conclusion and Future Work.

2. RELATED WORK
Moreno [3] reports web accessibility is characterized by "developing web resources so that all people can use it, regardless of technical, physical or cognitive limitations".

In this context, Höckner et al. [4] discuss about the project AccessibleMap, an initiative of the Ministry of Transport, Innovation and Technology of Austria on making maps more accessible for people with visual impairments. The main objective of the project is to develop methods for designing web-based maps, so people with limited vision, color blindness or total blindness can use them. According to the authors, AccessibleMap presents textual description of the map providing geometric and spatial information in written format, so screen readers and Braille displays can access it. The visual optimization of the map gives options for changing colors, size of objects, and the disposal of information according to user needs. The features implemented allow to: a) configure the map, for example, selecting a specific cartographic design, depending on user preference; b) access visual descriptions of the map and c) proceed with actions on the map, such as search and zoom.

Schneider [5] presents a system for web-based maps, where the main purpose is to assist localization in the Virginia Tech buildings complex, composed of more than 100 buildings. The author argues that finding a building or a room in the institution is a problem, thus justifying the need for a system to assist in these tasks. VTQuest [5] aims to solve these problems. In addition, the system aims to help people with special needs, whereas it implements accessibility via a user interface with audio interaction. The system provides a multimodal user interface, with voice, mouse and keyboard, and the user can choose which way best fits his or her needs [5].

Kaklanis [6] discusses about HapticRiaMaps, an application of accessible maps for web adapted for the visually impaired. The application uses map representations based on data from OpenStreetMap. Thus, all data from a specific area requested by the user, such as roads, street names, markers and other items, are imported in XML format. A 2D map is then created according to the information received with the structure of the streets and finally a pseudo-3D map is generated [6]. The user interaction with the application HapticRiaMaps is via assistive technologies of the haptic type, i.e., those that integrate the user to the

¹ Copyright is held by the authors. This work is based on an earlier work: SAC’15 Proceedings of the 2015 ACM Symposium on Applied Computing. Copyright 2015 ACM 978-1-4503-3196-8. http://dx.doi.org/10.1145/2695664.2695771.
application through touch. Therefore, it is necessary to handle the 3D map generated.

3. EVALUATION OF WEB ACCESSIBILITY ON THE MAPS DOMAIN

According to Aizpurua et al. [7], accessibility guidelines usually present generic accessibility tests, such as: automated tests, manual tests and semi-automatic tests or involving generic problems. The authors define the tests as: a) automated testing: a validation test that usually does not need or require to be done by a person and can be performed by a tool; b) manual or semi-automatic testing: requires the human component. These evaluations search for problems associated with code fragments that implement the website and c) generic problems: human presence required for evaluation because the item being evaluated cannot be associated with any code fragment. Brajnik [8] performs a comparative test of different evaluation methods for web accessibility, highlighting the importance of using more than one form of assessment during the accessibility evaluation process.

This paper presents in the next subsections the following accessibility evaluations: automated evaluation of accessibility by making use of evaluative tools; non-automatic accessibility evaluation with experts and non-automatic accessibility evaluation with end users.

The following evaluations analyzed items from WCAG 2.0 – Level A, the most basic level of the document (AA and AAA levels are composed of more complex accessibility guidelines). Level A presents itself in four different layers of guidance: principles, guidelines, success criteria and sufficient and advisory techniques. The principles provide the foundation for web accessibility: perceivable, operable, understandable, and robust. There are twelve guidelines under these principles, providing the basic goals that authors should work toward in order to make content more accessible.

For each guideline, WCAG 2.0 provides testable Success Criteria, in twenty-five items on its Level A. These Success Criteria are the ones used in the following evaluations. To facilitate implementation of guidelines it was also documented a wide variety of techniques.

3.1 Expert-Based Evaluation

The expert-based evaluation is a way to manually determine the existence of accessibility in an application [8].

According to Brajnik [8], the evaluation based on experts is one of the most used methods of assessment, being characterized as "an analytical method based on the opinions of evaluators, producing failures (in terms of checkpoints and success criteria violated) and pointing out defects and solutions".

3.1.1 GQM Approach: Goal-Question-Metric

There are several mechanisms known in the literature that can help define and set measurable goals in a particular process or activity, such as the Goals - Questions - Metrics (GQM) paradigm that proposes the definition, implementation, analysis and improvement of the processes [9]. According to Basili [9], measurements must be defined according to some specific objectives, in order to achieve effectiveness.

For this assessment based on experts, the following goals, questions and metrics were proposed:

- **Goal**: Analyze web-based mapping systems, in terms of accessibility, from the point of view of experts in web accessibility.
- **Question1**: Which Success Criteria from WCAG 2.0 - Level A - are implemented by the web systems evaluated?
- **Question2**: What level of compliance in WCAG 2.0 each web system can be classified?
- **Metric1**: Sum of Success Criteria that are not implemented by the systems, whereas the option given by experts in the questionnaire is “It does not meet”. This metric serves the Question1 and shall be applied in each one of the analyzed systems.

3.1.2 ISO/IEC 25040

The ISO/IEC 25040 [10] standard provides a guide and a reference model in software evaluation, in order to provide generic requirements for specifications and reviews of software quality. Also, according to the standard, the assessment process is the basis for evaluation of software product quality for different purposes and approaches. Thus, the process can be used to assess the quality of software already in use, development, or even in a pre-development stage.

The following steps, defined in ISO/IEC 25040 [10], were used: establish evaluation requirements, specify the evaluation, design the evaluation, execute the evaluation and conclude the evaluation.

Nielsen and Landauer [12] proposed that usability evaluation should not occur on systems making use of elaborated tests or even involving a large amount of test users. Rather, the authors demonstrated in their study that the majority of usability problems found on tests require just a few users. The authors also demonstrated that an ideal test case is based on applying the highest possible number of simple tests, involving an average of five to eight users. Thus, based on ISO/IEC 25040 and Nielsen and Landauer statements, the accessibility evaluation based on experts considered eight experts.

The selection of the experts was based on their background, knowledge and experience in the subject of Web Accessibility. At first, it was created a list of possible candidates and, after that, the selection proceeded based on the following criteria: academic degree, experience with web accessibility and development experience. At the end of the process, eight experts were selected. All of them with some experience or knowledge on web accessibility and three or more years working with software development; one expert about to finish college; two finishing Master’s degree; three with Master’s degree and one with doctoral degree. The selection of websites to be analyzed was based on: web applications belonging to the domain of maps, since they were widely used. Five web systems belonging to the domain of maps were chosen for evaluation with experts:

- OpenStreetMap - http://www.openstreetmap.org/
- Bing Maps - http://br.bing.com/maps/
- MapRequest - http://www.mapquest.com/

The form applied presented the twenty-five success criteria from WCAG 2.0 Level A, so that the answer to each question

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consisted of an alternative to be chosen among: a) fully meets; b) does not meet; c) does not apply to the site and d) partially meets.

The evaluation process was not conducted in the presence of the researcher. A total of eight evaluations were performed. Results of each success criteria for each web system according to experts point of view are presented in Table 1.

The experts were free to choose the most convenient method to be applied in the evaluation and they were given the choice to make use of screen readers or other tools that could contribute to the evaluation. The assessment occurred during October-November 2013. A checklist form containing all the Success Criteria of WCAG 2.0 - Level A - was given to the selected experts.

The experts analyzed the five selected websites, searching for some infringement of the Success Criteria. Item by item, the experts had to answer if the Success Criteria was fulfilled on that specific website.

For this, they could just try accessing a specific functionality and see the result, or analyzing the code searching for some problem, or using a screen reader to see if a specific element couldn’t be accessed.

The results were tabulated in order to identify the Success Criteria being violated. No significant troubles were reported by the experts in understanding the Success Criteria, and no mishaps of any kind or adverse situation that may compromise the results occurred.

3.1.3 Discussion

Table 1 presents the Success Criteria not met in the eight performed evaluations, and provides results to Metric1 and Question1, defined in Section 3.1.1.

Figure 1 presents graphs for analysis of individual systems. It is possible to observe that in all websites analyzed there are Criteria Success not met.

<table>
<thead>
<tr>
<th>Success Criteria</th>
<th>Google Maps</th>
<th>OpenStreet Map</th>
<th>Yahoo! Maps</th>
<th>Bing Maps</th>
<th>Map Request</th>
</tr>
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<tbody>
<tr>
<td>1.1.1 X</td>
<td>X</td>
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<td>4.1.2 X</td>
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<td>Total</td>
<td>18</td>
<td>4</td>
<td>8</td>
<td>10</td>
<td>4</td>
</tr>
</tbody>
</table>

Figure 1. Individual Analysis Results of Websites.
According to Table 1, on success criterion 1.3.1, no evaluation returned positive results, indicating that information regarding the content visually presented in the applications is not available to users. That is, the information is not accessible in a way that it reaches different users with different needs.

Four out of five websites analyzed had problems in criteria 2.4.1 and 3.3.1. According to Criterion 2.4.1, a mechanism should be available to bypass blocks of content that are repeated on multiple web pages; when this Success Criterion is not satisfied, it may be difficult for people with some disabilities to quickly and easily reach the main content of a web page [2]. Criterion 3.3.1 deals with textual corrections of errors in user inputs: in this kind of error, simple typos, for example, can preclude the user from accessing correctly the functionality. These results illustrate the need to implement mechanisms that meet the Success Criteria that weren’t fulfilled.

In order to answer Question 2 in Section 3.1.1, it is possible to say that, according to this evaluation by experts, none of the assessed websites implement Level A defined by WCAG 2.0, since several Success Criteria at this level are not contemplated.

### 3.2 Tool-Based Evaluation

Bach, Leal and Silveira [13] emphasize the importance of using automatic tools on web accessibility assessment, although they discuss that assessments should not be limited to such, since automated assessment tools do not consider aspects of human interaction. Next subsections present more details about the tool-based evaluation.

#### 3.2.1 Tools

Five tools were used in this evaluation. The AChecker tool [14] evaluates different sets of guidelines. The Total Validator tool [15] performs validation tests in HTML files in various WCAG guidelines and check for broken links and spelling problems in different languages. The CynthiaSays tool [16] also makes automated website analysis, including the three levels of WCAG 2.0 and Section 508. The TAW tool [17] provides the WCAG 2.0 Analyzer tool, which also makes the analysis of accessibility items provided by WCAG 2.0 in its three different levels. Finally, the AccessMonitor tool [18], which provides analysis on three levels of WCAG 2.0, was also used in this evaluation. The tool selection was based on the following criteria: to perform analysis on WCAG 2.0 - Level A and provide detailed analysis report.

#### 3.2.2 GQM Approach: Goal-Question-Metric

For this tool-based assessment, the following goals, questions and metrics were proposed:

- **Goal 1**: Analyze web-based mapping systems, in terms of accessibility by making use of automatic evaluation tools.
- **Question 1**: What compliance level of WCAG 2.0 accessibility each site can be classified, according to automatic evaluation tools?
- **Metric 1**: Sum of Success Criteria that are not implemented by systems which analysis returns as result "not implemented", "not met", or any similar nomenclature, which expresses that the success criterion has not been met. This metric helps to answer the Question 1, defined in this section.

#### 3.2.3 ISO/IEC 25040 Standard

This tool-based evaluation also used the ISO/IEC 25040 standard in order to support the activities of the evaluation. Thus, analogous to the experts’ evaluation, steps in conducting the evaluation were defined following ISO/IEC 25040 standards [10], such as establish evaluation requirements, specify the evaluation, design the evaluation, execute the evaluation and conclude the evaluation.

The evaluation consists of an automatic analysis considering web-based mapping systems and previously selected tools. Web systems selected for the evaluation are the same ones from experts’ evaluation. The tool-based evaluation was performed between November and December 2013, so that after the websites to be analyzed and the tools to be used were selected, the tools analysis was executed, generating a report for each analysis on the items investigated. The criteria used in the evaluation are the Success Criteria from WCAG 2.0 - Level A, so that each tool internally runs a checklist, checking if the Success Criteria are implemented or not by the application. Once the tools performed the tests on the selected websites, the results were tabulated and it was possible to determine which application had the biggest number of error and Success Criteria not met. Results are shown in Figure 2.

![Figure 2. Tool-based evaluation results.](image-url)
3.2.4 Discussion

In Figure 2 the total of errors found by the tools in web systems is presented. From these results, we observed that all the websites analyzed by the tools contain errors and Success Criteria not met, indicating accessibility problems within their elements and features. Considering that for all web systems the tools detected Success Criteria errors, it is possible to conclude, in response to the Question 1 from Section 3.2.2, that the websites are not in the Level A of the WCAG 2.0 guideline.

The tool-based evaluation aimed to identify success criteria that were not properly implemented by the analyzed websites. Five tools and five different websites were selected for the task, so that each tool selected tests performed on each of these websites, totaling twenty-five tests.

The first tool to proceed with the evaluations was AccessMonitor. It is an automatic validator that checks the implementation of accessibility guidelines in a website.

Table 2. Accessibility Evaluation from AccessMonitor tool – Success Criteria not met.

<table>
<thead>
<tr>
<th>Success Criteria</th>
<th>Google Maps</th>
<th>OpenStreet Map</th>
<th>Yahoo! Maps</th>
<th>Bing Maps</th>
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<td>X</td>
</tr>
<tr>
<td>Total of criteria not met</td>
<td>11</td>
<td>6</td>
<td>4</td>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>

AccessMonitor offers the options to enter a URL for analysis, load a HTML file or analyze only a fragment. It offers analyzes of WCAG 1.0 and WCAG 2.0 in the three levels of compliance and validation in CSS and HTML code.

In this evaluation, the URL of the websites were submitted on the tool and the analysis option was WCAG 2.0. The evaluation results provided by AccessMonitor tool are shown in Table 2. It presents also a field with the total of criteria not met.

The second assessment used AChecker tool. This tool provides evaluations from guidelines Section 508, WCAG 2.0 in its three compliance levels, BITV 1.0 and Stanca Act. It provides the options of evaluating HTML files, code snippets, or submit an URL. The tool also provides web and downloadable reports.

The results of the analysis of AChecker tool are displayed in Table 3, which shows the success criteria not met, according to the evaluation tool. The third assessment used CynthiaSays tool. Table 4 shows the analysis results of CynthiaSays evaluations.

Table 3. Accessibility Evaluation from AChecker tool – Success Criteria not met.

<table>
<thead>
<tr>
<th>Success Criteria</th>
<th>Google Maps</th>
<th>OpenStreet Map</th>
<th>Yahoo! Maps</th>
<th>Bing Maps</th>
<th>Map Request</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1.1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>1.3.1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2.1.1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2.4.1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3.1.1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3.2.2</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3.3.2</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>4.1.1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>4.1.2</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Total of criteria not met</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>

The following evaluation was performed with TAW tool. Table 5 shows the analysis results with TAW tool.

Table 4. Accessibility Evaluation from CynthiaSays tool – Success Criteria not met

<table>
<thead>
<tr>
<th>Success Criteria</th>
<th>Google Maps</th>
<th>OpenStreet Map</th>
<th>Yahoo! Maps</th>
<th>Bing Maps</th>
<th>Map Request</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1.1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>1.3.1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2.4.1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3.1.1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3.2.2</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3.3.2</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>4.1.2</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Total of criteria not met</td>
<td>7</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 5. Accessibility Evaluation from TAW tool – Success Criteria not met

<table>
<thead>
<tr>
<th>Success Criteria</th>
<th>Google Maps</th>
<th>OpenStreet Map</th>
<th>Yahoo! Maps</th>
<th>Bing Maps</th>
<th>Map Request</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1.1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>1.3.1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2.2.1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2.4.4</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3.1.1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3.2.2</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3.3.2</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>4.1.1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>4.1.2</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Total of criteria not met</td>
<td>9</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

Errors reported 128 12 14 24 32
The fifth and last analysis used TotalValidator tool. This tool makes the following analysis: HTML (including version 5.0), XHTML, CSS, WCAG 1.0 and 2.0 (levels A, AA and AAA), Section 508, spelling errors in six languages and broken links. It is available either as a plug-in for browsers, as in the form of downloadable local analysis of a website. Table 6 shows the evaluation results performed by TotalValidator tool.

Table 6. Accessibility Evaluation from TotalValidator tool – Success Criteria not met.

<table>
<thead>
<tr>
<th>Success Criteria</th>
<th>Google Maps</th>
<th>Open StreetMap</th>
<th>Yahoo! Maps</th>
<th>Bing Mapas</th>
<th>Map Request</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1.1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>1.3.1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3.2.2</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>4.1.1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>4.1.2</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Total of criteria not met</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

3.3 End-User Evaluation

According to Brajnik [8], there are many benefits of evaluation with users, such as the ability to identify usability problems that often cannot be found with automatic or expert reviews.

3.3.1 GQM Approach: Goal-Question-Metric

For this end-user assessment, the following goals, questions and metrics were proposed:

- **Goal1**: Analyze a web-based map, in terms of accessibility, utilizing end users.
- **Question1**: What features, among those offered by the application, can be accessed by visually impaired users?
- **Question2**: What features the users could find any barrier to access, precluding the use of the functionality?
- **Question3**: What level of ease of access and level of success users can develop the list of proposed activities?
- **Metric1**: Percentage of users who successfully accessed the functionalities analyzed, regardless of the degree of difficulty or degree of success in using them. This metric is applied to each proposed activity to the group of end users, and is calculated by (1):

  \[
  S = \frac{\text{sum of successful access in a functionality}}{\text{amount of evaluations performed}} \times 100
  \] (1)

  Through analysis of Metric1, it is possible to answer **Question1** and **Question2** from this section.

- **Metric2**: Necessary time to complete the proposed activities. This metric consists of the measured time that each user in each activity utilized to perform the asked task. The times are grouped and the average time for each activity is calculated, according to (2):

  \[
  S = \frac{\text{sum of the time spent by each user in the activity}}{\text{amount of evaluations performed}}
  \] (2)

  This metric should be applied for each activity and aims to answer **Question3**, defined in this Section.

- **Metric3**: Average level of difficulty encountered by users to complete the tasks. The following levels of difficulty were defined to classify the activities: a) fully achieved, without difficulties; b) fully achieved, with difficulties; c) partially achieved; d) not achieved. For this metric, each activity at each assessment is classified into one of the items above, so that in the end, an arithmetic average of the assessments can be made. In order to be possible to calculate this average, numerical values were assigned to each item, as follow:

  a) Fully achieved, without difficulties: 50 points;
  b) Fully achieved, with difficulties: 30 points;
  c) Partially achieved: 10 points;
  d) Not achieved: 0 points;

  The **Metric3** can be calculated by (3):

  \[
  S = \frac{\text{sum of the points from the activity in all evaluations}}{\text{amount of evaluations performed}}
  \] (3)

  The measure also seeks to assist in the resolution of **Question3**, defined in the present section.

3.3.2 ISO/IEC 25040 Standard

In a similar way to the previous two assessments, the ISO/IEC 25040 Standard [10] was used in this evaluation to define the different steps present in an evaluation.

The evaluation based on end-users took place during the period of February-March 2014, with visually impaired users from Institute for Blind Florivaldo Vargas - ISMAC, located in Campo Grande, state of Mato Grosso do Sul, Brazil.

The website selected was Google Maps (http://maps.google.com) due to its ease of use, popularity, and the fact that, among the websites analyzed in the other two evaluations, it contains the highest average number of accesses; according to TrafficEstimate tool [11]. It was created a list of activities that could evaluate the functionality in terms of accessibility.

These activities have been prepared considering all the websites analyzed in the other two evaluations presented in this paper. Thus, the activities, even if applied only to one website, are covering features that are common to this application domain.

The selection of users to participate in the evaluation was made according to the following criteria: a) at least 18 years old; b) be partially or totally blind and c) know how to operate a computer.
The evaluation took place individually, being performed by the visual impaired and accompanied only by the researcher. A total of eight participants could evaluate google maps. Each activity was timed and classified, being performed by the participant with the help of a screen reader.

The activities were classified by the users in order to be possible to identify the ones with accessibility problems. The possible classification options are: (A) fully achieved, without difficulties; (B) fully achieved, with difficulty; (C) partially achieved; and (D) not achieved. The activities description follows:

- Activity 1: lookup for an address, using the search field;
- Activity 2: find out the name of a neighborhood with a supplied address;
- Activity 3: switch between "Map" and "Satellite" views, using the website tools;
- Activity 4: access photos of a given address, and read their descriptions;
- Activity 5: find the function buttons to "get directions" and "my places";
- Activity 6: use function "get directions" with start and end addresses;
- Activity 7: use function "avoiding tolls" on a chosen path in a given address;
- Activity 8: change the path to “walking”;
- Activity 9: use the zoom feature on the map.

Table 7 presents the results obtained by the eight visually impaired users on the evaluation.

<table>
<thead>
<tr>
<th>Activity</th>
<th>U1</th>
<th>U2</th>
<th>U3</th>
<th>U4</th>
<th>U5</th>
<th>U6</th>
<th>U7</th>
<th>U8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity 1</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>Activity 2</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>A</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Activity 3</td>
<td>A</td>
<td>A</td>
<td>D</td>
<td>B</td>
<td>D</td>
<td>B</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>Activity 4</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>Activity 5</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Activity 6</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Activity 7</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Activity 8</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Activity 9</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
</tr>
</tbody>
</table>

Table 7. End-user evaluation – Classification of Activities.

Through analysis of Table 7, is possible to obtain the percentage of users who successfully accessed the functionalities, which is Metric1, described in Section 3.3.1.

- Activity 1: accessed successfully in eight out of eight evaluations: 8/8 × 100 = 100%
- Activity 2: accessed successfully in seven out of eight evaluations: 7/8 × 100 = 87.5%
- Activity 3: accessed successfully in four out of eight evaluations: 4/8 × 100 = 50%
- Activity 4: accessed successfully in zero out of eight evaluations: 0/8 × 100 = 0%
- Activity 5: accessed successfully in eight out of eight evaluations: 8/8 × 100 = 100%
- Activity 6: accessed successfully in eight out of eight evaluations: 8/8 × 100 = 100%
- Activity 7: accessed successfully in eight out of eight evaluations: 8/8 × 100 = 100%
- Activity 8: accessed successfully in eight out of eight evaluations: 8/8 × 100 = 100%
- Activity 9: accessed successfully in zero out of eight evaluations: 0/8 × 100 = 0%

3.3.3 Discussion

Analyzing the previous data, it is possible to answer the questions "Question1" and "Question2", from the Section 3.3.1, as follows:

- From a list of activities involving the common features of web-based mapping systems and one application:

**Question1**: Which of these features visually impaired users can access?

**Answer1**: The features used in Activities 1, 5, 6, 7 and 8 had no problems in access, while Activity 2 could not be accessed in one evaluation. The Activity 3 presented accessibility problems in four out of eight evaluations performed.

**Question2**: On what activities the users have found any access barrier, precluding the use of the functionality?

**Answer2**: Activities 2, 3 4 and 9. These barriers prevented the users, during the evaluations performed, to use the features affected, making it impossible to them to execute the asked task.

In Activity 2, only one user was unable to proceed with the access. In Activity 3, four evaluations resulted in unsuccessful access. In Activities 4 and 9, not a single visually impaired user completed the tasks, indicating possible severe accessibility problems.

The **Metric2** presented in Section 3.3.1, addresses the time required that each user used to complete the proposed activities from the list. Since each activity is designed to be similar, it is possible to identify the activities where users had more difficulties in its execution through the analysis of the spent time. Once obtained the evaluations times, the arithmetic mean equation (2) defined in Section 3.3.1 is utilized to obtain the average time required to complete each activity individually.

Once an activity took more time than others, it is possible to say that this activity may have some element that presents accessibility issues, being necessary further analysis. For each activity, it was given a limit of ten minutes to completion. Table 8 shows the execution times of activities obtained during the evaluations.
activities. The difficulty encountered by the users to complete the list of activities.

These values indicate and evidence which activities the users had troubles to fulfill or not. Table 10 shows the score of the presented. These values indicate and evidence which activities the users had troubles to fulfill or not. Table 10 shows the score of the activities obtained by assigning scores to each classification, as previously presented. These values indicate and evidence which activities the users had troubles to fulfill or not. Table 10 shows the score of the activities.

Table 8. End-user evaluation: time spent in the execution of activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>User 1</th>
<th>User 2</th>
<th>User 3</th>
<th>User 4</th>
<th>User 5</th>
<th>User 6</th>
<th>User 7</th>
<th>User 8</th>
<th>Total per Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity 1</td>
<td>3min25s</td>
<td>3min51s</td>
<td>3min18s</td>
<td>2min43s</td>
<td>5min19s</td>
<td>3min18s</td>
<td>4min19s</td>
<td>3min56s</td>
<td>30min09s</td>
</tr>
<tr>
<td>Activity 2</td>
<td>2min28s</td>
<td>4min08s</td>
<td>2min43s</td>
<td>2min33s</td>
<td>10min</td>
<td>2min19s</td>
<td>3min38s</td>
<td>3min39s</td>
<td>31min28s</td>
</tr>
<tr>
<td>Activity 3</td>
<td>5min33s</td>
<td>3min52s</td>
<td>10min</td>
<td>3min44s</td>
<td>10min</td>
<td>5min02s</td>
<td>10min</td>
<td>10min</td>
<td>58min11s</td>
</tr>
<tr>
<td>Activity 4</td>
<td>10min</td>
<td>10min</td>
<td>10min</td>
<td>10min</td>
<td>10min</td>
<td>10min</td>
<td>10min</td>
<td>10min</td>
<td>01h20min</td>
</tr>
<tr>
<td>Activity 5</td>
<td>2min15s</td>
<td>2min47s</td>
<td>2min23s</td>
<td>1min19s</td>
<td>2min41s</td>
<td>1min32s</td>
<td>1min21s</td>
<td>2min02s</td>
<td>16min20s</td>
</tr>
<tr>
<td>Activity 6</td>
<td>3min11s</td>
<td>3min55s</td>
<td>2min58s</td>
<td>2min31s</td>
<td>4min21s</td>
<td>2min49s</td>
<td>2min36s</td>
<td>5min38s</td>
<td>27min59s</td>
</tr>
<tr>
<td>Activity 7</td>
<td>2min13s</td>
<td>2min22s</td>
<td>1min45s</td>
<td>1min19s</td>
<td>2min19s</td>
<td>1min25s</td>
<td>1min21s</td>
<td>2min53s</td>
<td>15min37s</td>
</tr>
<tr>
<td>Activity 8</td>
<td>2min24s</td>
<td>1min55s</td>
<td>1min53s</td>
<td>1min32s</td>
<td>1min21s</td>
<td>1min43s</td>
<td>1min42</td>
<td>2min59s</td>
<td>15min29s</td>
</tr>
<tr>
<td>Activity 9</td>
<td>10min</td>
<td>10min</td>
<td>10min</td>
<td>10min</td>
<td>10min</td>
<td>10min</td>
<td>10min</td>
<td>10min</td>
<td>1h20min</td>
</tr>
<tr>
<td><strong>Total per evaluation:</strong></td>
<td><strong>41min29s</strong></td>
<td><strong>42min50s</strong></td>
<td><strong>45min00s</strong></td>
<td><strong>35min41s</strong></td>
<td><strong>56min01s</strong></td>
<td><strong>38min08s</strong></td>
<td><strong>44min57s</strong></td>
<td><strong>51min07s</strong></td>
<td></td>
</tr>
</tbody>
</table>

The total time spent per activity was divided by eight, which is the number of evaluations performed. Table 9 shows the average time spent on activities:

Table 9. Average time spent on activities.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Average activity time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity 1</td>
<td>03min46s</td>
</tr>
<tr>
<td>Activity 2</td>
<td>03min56s</td>
</tr>
<tr>
<td>Activity 3</td>
<td>07min16s</td>
</tr>
<tr>
<td>Activity 4</td>
<td>10min</td>
</tr>
<tr>
<td>Activity 5</td>
<td>02min02s</td>
</tr>
<tr>
<td>Activity 6</td>
<td>03min30s</td>
</tr>
<tr>
<td>Activity 7</td>
<td>01min57s</td>
</tr>
<tr>
<td>Activity 8</td>
<td>01min56s</td>
</tr>
<tr>
<td>Activity 9</td>
<td>10min00s</td>
</tr>
</tbody>
</table>

It is possible to conclude, from the analysis on the average time presented in Table 9 that activities 4 and 9 might have accessibility problems, once the blind users that tried to accomplish the task reached the time limit – 10 minutes – and failed to fulfill them.

Activity 3 also indicates it might have accessibility problems, since the average time for its execution is high, when compared to the other activities. These detected problems are detailed previously on this Section, answering **Question 2**.

**Metric3**, as defined in Section 3.3.1, aims to find the level of difficulty encountered by the users to complete the list of activities.

The sum of the points of each activity in the evaluations can be obtained by assigning scores to each classification, as previously presented. These values indicate and evidence which activities the users had troubles to fulfill or not. Table 10 shows the score of the activities.

Table 10. End-user Evaluation: Activities and its scores.

<table>
<thead>
<tr>
<th>Activity</th>
<th>U1</th>
<th>U2</th>
<th>U3</th>
<th>U4</th>
<th>U5</th>
<th>U6</th>
<th>U7</th>
<th>U8</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Act. 1</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>30</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>380</td>
</tr>
<tr>
<td>Act. 2</td>
<td>50</td>
<td>30</td>
<td>50</td>
<td>50</td>
<td>0</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>330</td>
</tr>
<tr>
<td>Act. 3</td>
<td>50</td>
<td>50</td>
<td>0</td>
<td>30</td>
<td>0</td>
<td>30</td>
<td>0</td>
<td>0</td>
<td>160</td>
</tr>
<tr>
<td>Act. 4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Act. 5</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>400</td>
</tr>
<tr>
<td>Act. 6</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>30</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>380</td>
</tr>
<tr>
<td>Act. 7</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>400</td>
</tr>
<tr>
<td>Act. 8</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>380</td>
</tr>
<tr>
<td>Act. 9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Applying the equation (3) defined in Section 3.3.1, it is possible to recategorize activities based on their average score, using the criteria specified on **Metric3** as it follows on Table 11.

Table 11. Average classification of the activities.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Average score</th>
<th>Average Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity 1</td>
<td>47.5 points</td>
<td>fully achieved, without difficulties</td>
</tr>
<tr>
<td>Activity 2</td>
<td>41.25 points</td>
<td>fully achieved, without difficulties</td>
</tr>
<tr>
<td>Activity 3</td>
<td>20 points</td>
<td>partially achieved</td>
</tr>
<tr>
<td>Activity 4</td>
<td>0 points</td>
<td>not achieved</td>
</tr>
<tr>
<td>Activity 5</td>
<td>50 points</td>
<td>fully achieved, without difficulties</td>
</tr>
<tr>
<td>Activity 6</td>
<td>47.5 points</td>
<td>fully achieved, without difficulties</td>
</tr>
<tr>
<td>Activity 7</td>
<td>50 points</td>
<td>fully achieved, without difficulties</td>
</tr>
<tr>
<td>Activity 8</td>
<td>47.5 points</td>
<td>fully achieved, without difficulties</td>
</tr>
<tr>
<td>Activity 9</td>
<td>0 points</td>
<td>not achieved</td>
</tr>
</tbody>
</table>

The answer to Question 3, defined in Section 3.3.1, follows:
Question3: What level of ease of access and level of success users can develop the list of proposed activities?

Answer3: Most of the proposed activities could not only be accessed but also completed successfully due to difficulty by visually impaired users. Nine activities were proposed to the users, and in six of them (Activities 1, 2, 5, 6, 7 and 8) we did not observe significant problems both in terms of accessibility and performing activities. In Activity 3, there were significant access problems: according to Table 7, 50% of visually impaired users could not access the information necessary to complete the task, whilst 25% were able to complete the task, but with difficulty, classifying the activity, on average, as “partially achieved”. It is also possible to identify in Metric2 that Activity 3 showed high average time to perform, indicating accessibility problems. In the two remaining activities (Activities 4 and 9) there were significant problems of access, so that none of the users in any of the evaluations have successfully accessed the elements of the website and got to complete the activities. These activities achieved the maximum execution time, as defined in Metric2, indicating that there were no success on the tasks, in terms of accessibility.

4. CONCLUSION AND FUTURE WORK

According to the assessments performed, it is possible to observe the existence of problems regarding the accessibility on the domain of web-based map applications. In the expert-based evaluation, there are several Success Criteria not met, making it impossible for the visually impaired user to perform specific tasks. None of the websites examined by experts reached the Level A of WCAG 2.0 conformance, since several Success Criteria for this level have not been met. All websites analyzed presented accessibility problems in the tool-based evaluation. Tools used for the automatic evaluation performed tests on the same websites used in the expert-based evaluation, aiming to identify Success Criteria that were not being met. It was detected that Google Maps showed a greater number of errors than other websites, due to Success Criteria not implemented. Moreover, Success Criteria not met were found in all analyzed websites and according to the evaluation tools, the websites did not reach Level A of WCAG 2.0.

In the end-user evaluation, it was found that elements responsible for zooming the map were not accessible via keyboard, so the screen reader could not read these features to the users. Other minor problems and difficulties observed by the researcher in this end-user evaluation were: navigability between fields; edit text fields without proper description; changing the visualization mode of the map; and “photos” is not properly described; elements with no indication of their type/functionality; possibility of using keyboard commands not clearly informed to the user. From these access barriers encountered in the user-based evaluation, which violates several WCAG 2.0 Success Criteria, it is possible to conclude that the web systems cannot be considered Level A in this guideline.

The evaluations presented in this paper identified several accessibility problems in the websites analyzed due to non-implementation of the Success Criteria defined in WCAG - Level A. These problems preclude the user that is in a specific condition to have full access to the tool functionality, making it impossible to make proper use of the technological tool offered. The results obtained in this study provide basis for future research and implementation in the area of the problems identified.

5. REFERENCES

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An ISO-based Software Process Ontology Pattern Language and its Application for Harmonizing Standards

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ABSTRACT
Many efforts have been made for modeling and standardizing software processes. ISO/IEC JTC1/SC7, the ISO sub-committee responsible for software and systems engineering, is one of the most important groups devoted to this task. However, standards developed by this committee are frequently inconsistent and even contradictory. This led to the need for an ISO Study Group to investigate the creation of an ontological infrastructure to establish a common conceptualization for underpinning all SC7 standards. This ISO initiative is a work in progress, which has focused on the software process domain and, in particular, considering the ISO/IEC 24744 standard. In this paper, we advocate in favor of using an Ontology Pattern Language (OPL) as the main component of this ontological infrastructure. We present ISP-OPL (ISO-based Software Process OPL), an OPL that can be applied as a basis for harmonizing software process-related ISO standards, favoring reuse when building aligned specific software process ontologies for Software Engineering sub-domains. In order to evaluate its applicability, we conducted an experiment involving seven domain ontologies, developed using ISP-OPL.¹

Categories and Subject Descriptors
D.2.9 [Software Engineering]: Management – software process models.
D.2.13 [Software Engineering]: Reusable Software – reuse models.

General Terms
Design, Experimentation, Standardization, Languages.

Keywords
Ontology development, ontology patterns, ontology pattern language, standards harmonization, software process.

1. INTRODUCTION
A permanent challenge in Software Engineering (SE) is to deal with quality aspects, improving the resulting products with higher productivity and lower costs. Since the quality of a software product depends heavily on the quality of the software process used to develop it, software organizations are investing more and more in improving their software processes. In this context, several process-related quality standards and maturity models, such as ISO/IEC 12207 [11], ISO/IEC 15504 [14], and CMMI [28], are used to guide software organizations efforts towards quality software processes. These initiatives attempt software process improvement by means of disseminating best practices in an organized and standardized way. However, most of the models and standards are created independently, without necessarily sharing the same semantics. This frequently gives rise to inconsistencies between them. This problem is amplified when different standards are used together, causing semantic interoperability problems [24]. Even standards proposed by the same standardization organization present this problem. This is due to the fact that each standard defines its own scope, structure of process entities, terms and definitions, amongst other things [22].

The International Organization for Standardization (ISO) recognizes this problem. SE standards developed by ISO/IEC JTC1's SC7 (the ISO sub-committee responsible for software and systems engineering standards) frequently employ terms whose definitions vary significantly across standards. In order to treat this problem, ISO created, in 2012, a study group to develop an ontological infrastructure aiming to be a single coherent underpinning for all the SC7 standards [9]. The goal is to establish a basic set of definitional ontologies, which can be used to derive more specific ontologies. These specific ontologies are meant to address different SE sub-domains (e.g., Software Testing), which in turn are the subject of specific SC7 standards (e.g., ISO/IEC/IEEE 29119 [18]) [9]. The ISO initiative is a work in progress, which has focused on the definitional ontologies, taking mainly ISO/IEC 24744 [16] into account. The goal is to develop a Definitional Elements Ontology (DEO) and an aligned Configured Definitional Ontology (CDO) based on ISO/IEC 24744, which could be extended for building Standard Domain Ontologies (SDOs).

We argue that this basic set of definitional ontologies (DEO and CDO) should be represented as core ontologies on software processes, from which the more specific SDOs could be derived. According to [27], a core ontology provides a precise definition of structural knowledge in a specific field that spans across different application domains in this field. Moreover, we argue that, by following a pattern-oriented approach, a core ontology can systematically become more modular and extensible [5].

A core ontology for the ISO harmonization initiative should be: (i) flexible enough for allowing ontology engineers to explore alternative models in the design of specific ontologies for the
various software process sub-domains; (ii) modular, in order to allow the ontology engineer to select the ontology fragments relevant to the problem at hand and then reuse it; and (iii) broad enough to cover the general concepts in the software process universe of discourse. For achieving these characteristics, we argue that this core ontology should be organized as an Ontology Pattern Language (OPL). An OPL is a network of interconnected domain-related ontology patterns that provides support for solving a class of ontology development problems for a specific domain. An OPL offers a set of interrelated domain patterns, and a process with explicit guidance on what problems can arise in that domain, informing the order to address these problems, and suggesting one or more patterns to solve each specific problem [5].

A core ontology should also be precise. This is achieved by basing the core ontology on a foundational ontology [27]. Thus, as the starting point for this work, we performed an ontological analysis of the ISO/IEC 24744 metamodel [24] in the light of the Unified Foundational Ontology (UFO) [7]. Based on the results obtained from this ontological analysis, and inspired on a Software Process OPL presented in [5], we have defined the ISO-based Software Process OPL (ISP-OPL).

The main purpose of ISP-OPL is to provide a sound solution for building ontologies in the software process domain, taking ISO standards as the main source of knowledge. This version of ISP-OPL focuses on the project (or endeavor) level, and addresses three main aspects dealt by ISO software process standards: Work Units, including patterns to define the decomposition, dependence, and scheduling of work units; Work Products, considering the nature of software process work products and how they are handled; and Human Resources, dealing with how people are organized in teams, allocated to tasks and perform work units. In order to evaluate ISP-OPL and its applicability, we performed an experiment encompassing the development of seven domain ontologies for SE sub-domains considering mainly ISO/IEC 12207, but also other related standards, such as CMMI [28].

This paper is organized as follows. Section 2 discusses the ISO standard harmonization initiative and the notion of Ontology Pattern Language. Section 3 presents ISP-OPL. Section 4 depicts how the experiment was conducted and the obtained results, including an ISP-OPL application example for the Requirements Engineering process. Section 5 discusses related work. Finally, Section 6 presents our final considerations.

2. ISO STANDARD HARMONIZATION
AND ONTOLOGY PATTERN LANGUAGES

Standard harmonization is very important for organizations that seek to solve multiple needs at their different hierarchical levels by using multiple standards [22]. In these cases, standards are frequently used in combination. For instance, organizations use general standards for system development, along with standards that expand on specific processes such as software testing or risk management [9]. Moreover, frequently, organizations also want to combine standards from different sources [8, 22].

Harmonious combination of standards is aided when the standards use consistent concepts. At the beginning of 2012, in the ISO SC7 plenary meeting, a set of problems was raised, among them the following [9]: (i) there is no guidance on how to build a new standard ensuring that it is compatible with other SC7 standards; (ii) clashes in the terminology and in the semantics are observed in the current standards. Resulting from the discussion in this meeting, a study group was created, charged with the goal of investigating the potential utility of ontologies for rationalizing SC7’s suite of SE International Standards [9].

This study group has proposed a layered framework comprising an ontology network [9]. In the top of the proposed framework, there is the Definition Elements Ontology (DEO), which provides definitions for concepts, and constraints that dictate how they must be related. From DEO, a Configured Definition Ontology (CDO) can be defined. The only CDO being worked to date is a CDO for the ISO/IEC 24744 metamodel (Software Engineering Metamodel for Development Methodologies – SEMDM) [16]. From a CDO, ontologies specific to particular standards, called Standard Domain Ontologies (SDOs), can be derived. The framework also considers in the future, to extend DEO by considering ontological distinctions put forward by foundational ontologies [7]. This extension is called Advanced Foundational Ontology for Standards (AFOS) [9].

SEMMD is the main basis for the entire framework, providing semantics for all ISO/SC7 standards. However, for the success of such initiative, the consistency of this ontological basis is crucial. Thus, in [24], we performed an ontological analysis of SEMMM in the light of the Unified Foundational Ontology (UFO) [7]. With this approach, we aim at providing a truly ontological foundation to the ISO framework. Moreover, we do not need a new foundational ontology (AFOS), but we can rely on an existing foundational ontology, in this case UFO. In [24] we identified several consistency problems in SEMMM fragments, and reengineered these model fragments, based on our ontological analysis.

The CDO based on the SEMMD is meant to be reused and extended in the development of several SDOs for specific software processes, such as Requirements Engineering process (ISO/IEC/IEEE 29148 [19]) and Software Testing process (ISO/IEC/IEEE 29119 [18]). For this reason, ontology patterns (OPs) arise as a promising alternative to organize the ontology framework, maintaining the actual benefits, and improving it to a modular and reusable solution [5]. In such approach, a domain ontology typically results from the composition of several OPs, with appropriate dependencies between them, plus the necessary extensions based on specific needs [2]. However, in order to truly favor reuse, organizing OPs in catalogues is not enough. A pattern language can provide a stronger sense of connection between the patterns, since it expresses several types of relationships among them, such as relations of dependence, temporal precedence of application, or mutual exclusion [5].

An Ontology Pattern Language (OPL) aims to provide holistic support for using domain-related OPs in ontology development. To ensure a stable and sound application of patterns, the patterns are presented in a suggested application order. OPLs encourage the application of one pattern at a time, following the order prescribed by paths chosen throughout the language [5].

In the next section, we present the ISO-based Software Process OPL (ISP-OPL), which has been developed aiming at supporting the ISO Harmonization Initiative.

3. AN OPL FOR ISO SOFTWARE
PROCESSES

The aspects addressed by ISP-OPL are: Work Units (WU), Human Resources (HR) and Work Products (WP). The patterns in ISP-OPL were extracted from the reengineered fragments resulting from the ontological analysis of the SEMMD [24], as well as from the Enterprise OPL (E-OPL) proposed in [6].
Figure 1 presents a UML activity diagram showing the language paths of ISP-OPL. As suggested in [5], in this activity diagram, Domain-Related Ontology Patterns (DROPs) are represented by action nodes (the labeled rounded rectangles); initial nodes (solid circles) represent entry points in the OPL, i.e., DROPs in the language that can be used without solving other problems first; control flows (arrowed lines) represent the admissible sequences in which DROPs can be used; merge points (diamond-shaped symbols) represent the merge of paths in the OPL; join/fork nodes (line segments) represent the conjunction of paths (join) or independent and possibly parallel paths (fork); finally, an extension to the original UML notation (dotted lines with arrows) is used to represent variant patterns, i.e., patterns that can be used to solve the same problem in different ways. Moreover, patterns are grouped according to the software process aspect to which they are related: the three big boxes for Work Units, Human Resources and Work Products.

As Figure 1 shows, ISP-OPL has three entry points. The ontology engineer should choose one of them, depending on the scope of the specific software process ontology being developed. The ontology engineer should choose EP1, when the requirements for the new ontology include the definition and planning of work units; she should choose EP2, if the scope of the ontology considers only the execution of work units (performed WUs); EP3 is to be chosen if the ontology engineer aims to model only the structure of work products.

Through entry point EP1, in order to model the structure of WUs, the ontology engineer needs to choose one of (or both) the patterns WU Composition (WUC) and WU Dependence (WUD). These patterns are used to represent work units defined in an endeavor, without planning a time frame for them. WUC represents the mereological decomposition of work units, specializing Work Unit into Process, Composite Task and Simple Task. WUD deals with the dependence between work units. The Project Process Definition (PPD) pattern captures the link between a Process and the Project to which it is defined. The WU Scheduling (WUS) pattern is used to represent the time frame of a scheduled WU, defining its planned start and end dates. Next, the ontology engineer can focus on modeling performed work units, i.e., work units already executed. Performed WUs, as past events, have actual start and end dates. The tracking of performed work units against defined work units is treated by the Performed WU Tracking (PWUT) pattern, which relates a Scheduled Work Unit to a Performed Work Unit caused by the former. The group encompassing the patterns Performed WU Composition (PWUC) and Performed WU Dependence (PWUD) uses a similar structure to the group containing WUC and WUD. Additionally, the Project in which a Process is performed can be modeled with the Project Process Performing (PPP) pattern.
If the requirements for the ontology involve only performed work units, the entry point is EP2, allowing using only the patterns PWUC, PWUD and PPP. Figure 2 shows the complete model of the Work Unit group of patterns, detaching each pattern. Every pattern (of Figure 2 and the following) is represented using OntoUML. OntoUML is a UML profile that enables making finer-grained modeling distinctions between different types of classes and relations according to the ontological distinctions put forth by the Unified Foundational Ontology (UFO) [7].

After modeling Work Units related aspects, the ontology engineer can address human resource related problems by applying the patterns of the Human Resource group (shown in the right side of Figure 1). The Human Resource Employment (HRE) pattern establishes the employment relation between an Organization and a Person, which assumes the Human Resource role. This pattern was adapted from the Employment pattern of the Enterprise OPL (E-OPL) [6]. The Stakeholder Definition (StD) pattern defines the concept of Stakeholder (someone involved in a Project), and distinguishes between two types of stakeholders: Person Stakeholder and Team Stakeholder. Figures 3 and 4 show the patterns HRE and StD, respectively.

The Organizational Team Definition (OTD) and Project Team Definition (PTD) patterns are used to define organizational and project teams, respectively. Both are also adapted from homonymous patterns from the E-OPL. Figure 5 shows these two patterns.

In order to represent the membership relation between a team and its members (persons), the ontology engineer can choose one of the alternative patterns Team Membership Simplified (TMS) and Team Membership with Role (TMR), which are shown in Figure 7.

Two alternative patterns can be used to represent the allocation of stakeholders to a scheduled work unit: Stakeholder Allocation (StA) and Stakeholder Allocation Simplified (StAS). As Figure 8 shows, StA models the relational property (relator) Stakeholder...
Allocation that glues the stakeholder to the scheduled work unit and to the organizational role the stakeholder plays. Moreover, the planned start and end dates for the stakeholder allocation are captured. StAS is a simplified version that omits the relator, capturing only the material relation linking stakeholders to scheduled work units.

Figure 7. The Alternative Patterns Team Membership with Role (TMR) and Team Membership Simplified (TMS)

Figure 8. The Alternative Patterns Stakeholder Allocation (STA) and Stakeholder Allocation Simplified (STAS)

Finally, for dealing with the participation of stakeholders in performed work units, the ontology engineer can choose between the alternative patterns Producer Participation (PPa) and Producer Participation Simplified (PPaS). The difference between these patterns refers to whether the relator Producer Participation is explicitly represented or not (respectively), as Figure 9 shows.

Figure 9. The Alternative Patterns Producer Participation (PPa) and Producer Participation Simplified (PPaS)

The last group of patterns constituting ISP-OPL is the group related to Work Products (WP). This group can be achieved from the patterns related to Performed WU, but also through the entry point EP3, which is to be chosen when the ontology engineer wants to represent only the structure of work products. The WP Composition (WPC) pattern allows modeling work product mereological decomposition. WP Nature (WPN) is related to types of work products (such as Document, Model and Information Item). Once applied WPN, Document Depiction (DocD) pattern can be used to model the fact that documents depict other work products. Figure 10 shows these three patterns.

Figure 10. The Patterns WP Composition (WPC), WP Nature (WPN) and Document Depiction (DocD)

When the patterns for work unit execution are already applied (through EP1 or EP2), beyond the work product structure, the ontology engineer can also model work products handling. In this case, WP Participation (WPPa) pattern sets the participation of work products in performed work units. The relator Work Product Participation is modeled with its specializations for creation, change and usage participation. Alternatively, these three types of participations can be modeled only by means of the corresponding material relations using the patterns WP Creation (WPcrea), WP Change (WPchan) and WP Use (WPuse), as Figure 11 shows.

Figure 11. The Work Product Participation Patterns

It is important to highlight that, since the patterns constituting ISP-OPL are described in OntoUML, they carry out the ontological and formal semantics of its modeling constructs such as kind, category, role mixin, relator, mode, mixin, material relation, etc. OntoUML is itself a pattern-based language (albeit a domain-independent one), whose modeling primitives are patterns that embody the micro-theories comprising the foundational ontology UFO [8]. As a consequence, the patterns of ISP-OPL are systematically constructed via the manifestation of the ontology-based patterns of OntoUML and UFO. For instance, in the patterns WUC and PWUC (Figure 2) and WPC (Figure 10), we have the direct manifestation of the UFO pattern (micro-theory) of...
Mereological Relations [7]. Moreover, in the patterns PPa (Figure 9) and WPPa (Figure 11), we have the direct manifestation of the OntoUML Relator pattern [7]. Finally, in the pattern StD (Figure 4), we have the manifestation of Roles with Multiple Disjoint Allowed Types pattern, or simply, the Role Mixin pattern [7]. As one will be able to observe in the next section, the structures constituting these patterns are carried out and presented in the ontologies created using ISP-OPL.

In order to fully document ISP-OPL for users, we developed the ISP-OPL Specification, version 1.0 (available at http://nemo.inf.ufes.br/OPL). This specification presents ISP-OPL Process and describes each DROP in detail, considering: the pattern name, intent, rationale, competency questions, conceptual model, and axiomatization. Table 1 shows the description of the Performed WU Composition (PWUC) pattern.

In the next section, we discuss an experiment applying ISP-OPL for developing seven domain ontologies for Software Engineering sub-domains, taking standards into account.

4. APPLYING ISP-OPL

Software processes encompass a wide number of sub-domains, such as Requirements Engineering, Architectural Design, Detailed Design, Project Management, Quality Assurance, Measurement, Risk Management, etc. For several of them there are standards covering their definitions, activities and related assets. In the context of the ISO Harmonization Initiative, beyond the core knowledge about software process (aimed to be represented by the definitional ontologies), it is necessary to represent each one of these sub-domains. Moreover, it is important that the sub-domain models may be derived from CDOs, originating each of the required SDOs. This section presents an empirical study performed in order to demonstrate how this derivation process can be supported by the application of ISP-OPL for building domain ontologies.

The experiment involved the development of seven domain ontologies representing different sub-domains described by Software Engineering standards. Section 4.1 discusses the experiment design, including the experiment plan and the subjects’ profile. Section 4.2 presents, as an example of ISP-OPL application, the Requirements Engineering Process ontology. Finally, Section 4.3 discusses the experiment analysis and main results.

4.1 Experiment Design

The main goal of this experiment was to evaluate ISP-OPL, collecting indicators and other relevant information about its application. Some important questions to answer are related to how the guidance provided by ISP-OPL affects the productivity of ontology engineers when developing domain ontologies for Software Engineering sub-domains; and how the use of ISP-OPL can improve the quality of the resulting ontologies.

The empirical study was conducted following the guidelines presented in [20]. The experiment took place during the second semester of 2014, as part of the course “Ontologies for Software Engineering”, an advanced course for graduate students in the Graduate Program in Informatics at Federal University of Espírito Santo, in Brazil.

The subjects of the experiment were 19 graduate students with at least basic knowledge in conceptual modeling. A questionnaire was applied to capture the participants’ profile, analyzing their level of education, experience in conceptual modeling, experience in ontology development, and experience with OPLs.

![Diagram of the PWUC Pattern Specification](image)

Table 1. The PWUC Pattern Specification

<table>
<thead>
<tr>
<th>PWUC – Performed WU Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Name:</strong> Performed WU Composition (PWUC)</td>
</tr>
<tr>
<td><strong>Intent:</strong> To represent the composition of performed work units in terms of other performed work units.</td>
</tr>
<tr>
<td><strong>Rationale:</strong> Performed Work Units can be composed of other performed work units. Mereologically, a performed work unit is simple, or composed of two or more parts. At the basic level, there are Performed Simple Tasks that can compose other performed work units, but are not decomposable. Performed Composite Tasks, in turn, are composed of other performed tasks (composite or simple performed tasks). At the higher level, Performed Processes are also composed of performed tasks, but do not compose any other performed work unit.</td>
</tr>
<tr>
<td><strong>Competency Questions:</strong></td>
</tr>
<tr>
<td>• Concerning their mereological structure, what are the possible types of performed work units?</td>
</tr>
<tr>
<td>• How is a performed work unit composed of other performed work units?</td>
</tr>
</tbody>
</table>

**Conceptual Model**

![Conceptual Model Diagram]

**Axiomatization**

A1: \( \forall w,c \, \text{partOf}(w,c) \rightarrow (w \equiv c) \)

A Performed Work Unit cannot be part of itself.

A2: \( \forall p: \text{PerformedProcess}(p) \rightarrow \lnot \exists w \)

PerformedWorkUnit\((w) \land \text{partOf}(p,w)\)

A Performed Process cannot be part of any Performed Work Unit.

A3: \( \forall w1,w2: \text{partOf}(w2,w1) \rightarrow (w2.\text{startDate} >= w1.\text{startDate}) \land (w2.\text{endDate} <= w1.\text{endDate}) \)

A Performed Work Unit that is part of another should occur within the time interval of its whole.

Regarding the profile, all participants were students in the Computer Science area, being around 90% of master degree students, and 10% of PhD students. Concerning the experience in conceptual modeling, 32% informed low experience (less than one year), 47% declared medium experience (from one to three years), and 21% have high experience (more than three years). Regarding the experience in ontologies development, we had 47% having their first experience developing an ontology in this experiment, 37% with low experience (less than one year), 16% with medium experience (from one to three years), and no one...
declared high experience (more than three years). Finally, all participants had the first experience with OPLs in this experiment. Therefore, we can say that the group of subjects has, mostly, medium experience in conceptual modeling, low experience in ontologies development and no experience with OPLs.

The course in question covers the following topics: Ontologies - Types and Definitions; Ontologies and Software Engineering; Ontology Development with Ontology Patterns; Ontologies for the Software Engineering Domain; and Applications of Ontologies in Software Engineering. The course instructor (the second author) taught the entire course, except for the ISP-OPL tutorial, which was taught by the first author. The object of study, ISP-OPL, was presented for the class and its specification was made available. The Requirements Engineering domain was taken as example, and the ISP-OPL authors developed this domain ontology, and made it available for the experiment participants. This ontology was also presented for the class.

The participants were divided into seven groups. Each group received one topic covered by the following ISO/IEC 12207 Software Processes: Human Resource Management, Measurement, Risk Management, Software Architectural Design, Software Configuration Management, Software Documentation Management, and Software Maintenance. They had a period of two months between the presentation of the ISP-OPL and the delivery of the domain ontology and related documentation. We had to conduct the study as a homework assignment, because ontology development took a long time to complete.

The experiment had four phases: (i) study of the domain, (ii) development of the domain ontology, (iii) evaluation of the resulting domain ontologies, and (iv) application of questionnaires and interviews.

First, the participants had to study software process standards and models for understanding the domain knowledge. The groups took as basis ISO/IEC 12207 [11], and ISO specific standards for each domain (e.g., ISO/IEC 15939 [15] for Measurement, ISO/IEC/IEEE 15289 [17] for Documentation, and ISO/IEC 14764 [12] for Maintenance). Since ISO standards are usually neutral concerning some process aspects such as work products and human resources roles, additionally, the participants used also the following models: CMMI [28], MR-MPS-SW [26] and SWEBOK [3].

The second phase has started with the presentation of ISP-OPL in class, with the application example for the Requirements Engineering Process domain (see Section 4.2). All the groups had access to the ISP-OPL Specification and to the ontology documentation for the example. Each group had to develop an ontology for the specific sub-domain chosen. The scope for the ontologies included only dealing with performed work units, work products handled by them, and stakeholder participations. As result, each group had to deliver a Reference Ontology Specification, containing the following information: domain ontology purpose, a brief description of the sub-domain being addressed, the sequence of the patterns application, competency questions, domain ontology models (OntoUML models), a glossary of the concepts in the ontology, and a mapping between the concepts in the ontology and the concepts present in the standards used.

In the third phase, the first and the second authors of this paper evaluated the resulting Ontology Specifications. This evaluation allowed us to identify several findings about ISP-OPL and its use, as discussed in Section 4.3.

The last phase involved the application of a questionnaire, the conduction of interviews, and the analysis of the collected data. After delivering the Ontology Specification, the participants answered, individually, a questionnaire with 14 questions divided into two parts. The first part focused on the understandability of the OPL process and its elements; the second part regarded the use of ISP-OPL for creating a domain ontology. In this second part, two questions used a Likert Scale, namely: (i) “Do you consider that the OPL application contributed for the quality of the resulting ontology?”; and (ii) “If you already have a previous experience in developing ontologies, do you consider that the OPL application contributed for the productivity in the ontology development process?”, wherein the responses could be: completely disagree, disagree, indifferent, agree, and totally agree. Another question used a scale of difficulty, namely: “How hard was to use ISP-OPL for creating a domain ontology?”, wherein the responses could be very hard, hard, neutral, easy and very easy. In the three cases, the participants were asked to justify their responses. Finally, there were two open questions: (i) “What were the difficulties you found for integrating the selected patterns?”, and (ii) “Describe (briefly) the process you followed for developing the ontology by applying ISP-OPL”.

Finally, after analyzing the questionnaire responses, an interview was conducted with each group. A structured interview was prepared. The questions analyzed the perception of the interviewees about the OPL, the process of using the OPL, the patterns, and the group experience using ISP-OPL for creating a domain ontology. Section 4.3 presents the analysis of the main findings collected in this phase.

4.2 The Requirements Engineering Process Ontology

In this section, we present part of an ontology we have developed for the Requirements Engineering (RE) process. In the context of the experiment, the RE Process ontology served as the first application of ISP-OPL, as well as an example for the development of the other domain ontologies by the participants of the experiment. We chose this process, due to its importance as a basis for software development, with concepts appearing in several standards, and because it is a well-known domain for the experiment subjects. The RE Process Ontology was derived from ISP-OPL according to the information extracted from selected ISO SC7 standards, namely: ISO/IEC 15288:2008 – System life cycle processes [13], ISO/IEC 12207:2008 – Software life cycle processes [11], and ISO/IEC/IEEE 29148:2011 – Requirements Engineering [19]. These are the main ISO standards dealing with requirements processes, from which our competency questions were defined. Together, the standards define three requirements-related processes: Stakeholder Requirements Definition, System Requirements Analysis, and Software Requirements Analysis. We present here only the sub-ontology addressing the first process: Stakeholder Requirements Definition (Section 6.4.1 in ISO 12207 and ISO 15288, and Section 6.2 in ISO 29148).

Figure 12 shows the chosen patterns and paths of the ISP-OPL process that we followed for developing this ontology. Figure 13 presents the Stakeholder Requirements Definition Process sub-ontology. On the top, the concepts with colored background are the ones defined as part of the ISP-OPL patterns. On the bottom, the concepts with blank background are the specific ones from the RE Process Ontology. Relations in the RE Process Ontology are specializations of the homonymous relations in the OPL. Cardinalities are omitted for the sake of legibility.
We are interested in describing the execution of requirements processes, including the participations of human resources and work products, as it is the case of organizations adopting these standards in their projects. Thus, we start using ISP-OPL through the entry point EP2. As defined in the aforementioned standards, the Stakeholder Requirements Definition process is decomposed in activities, which, in turn, are decomposed in tasks. Thus, we start with the Performed WU Composition pattern, modeling the decomposition of performed work units. The Stakeholder Requirements Definition Process is a subtype of Performed Process. This specialized process is composed of five work units: Stakeholder Identification, Requirements Identification, Requirements Evaluation, Requirements Agreement and Requirements Recording. The first and fourth work units are Performed Simple Tasks, and the others are Performed Composite Tasks, decomposed into simple tasks as shown in Figure 13.

Another pattern considered useful here is PWUD, which defines dependencies between work units. Although the selected standards do not explicitly set dependencies between tasks, some of them can be easily inferred from the nature of work units and work products handled, as well as by considering the RE literature. Thus, we applied the Performed WU Dependence pattern and established dependencies between the work units, as shown in Figure 13. Still regarding work units, the last pattern applied is Project Process Performing, establishing the connection between the Performed Process and the Project wherein it is performed.

Figure 12. ISP-OPL Patterns and Paths followed

Figure 13. The Requirements Process Ontology (Stakeholder Requirements Definition Process sub-ontology)
Once work units are addressed, we can represent human resources. Due to the general nature of the standards, few information is given about human resources participating in work units. Thus, we have modeled only the stakeholder definition and its relation with work units. The first pattern applied is Stakeholder Definition, to establish the stakeholder structure to be adopted. We consider only two types of stakeholders: System Analyst (suggested, but not explicitly named in the standards), and Requirements Stakeholder. Both are Person Stakeholders involved in the Project. Aiming to represent the participation of stakeholders in work units, the Producer Participation Simplified pattern is used, specializing stakeholders as Producers, in order to participate in Performed Work Units.

The other path of ISP-OPL we followed is through the use of work products patterns. Once we have different types of work products, it is useful to distinguish between them by applying the WP Nature pattern. Two subtypes of Work Product are considered: Information Item and Document. In the context of the Stakeholder Requirements Definition Process, we identified the following subtypes of Information Item: Requirement (in turn, specialized into Stakeholder Requirement), Stakeholder List, Stakeholder Agreement, and Traceability Record. Moreover, two sub-types of Document are considered: Requirements Evaluation Doc, and Stakeholder Requirements Specification (referred as StRS in ISO 29148). The StRS is the main result of this process and aggregates the Stakeholder List and the set of Stakeholder Requirements. Thus, using the WP Composition pattern, we establish StRS as a Composite Work Product (the only one in the ontology), composed of Stakeholder Requirements and Stakeholder List (Simple Work Products). Additionally, by applying the Document Depiction pattern, StRS, as a document, also depicts the Stakeholder Requirements.

Finally, by using the patterns WP Creation, WP Use and WP Change, we established the relationships of creation, usage and change between the work units of the Stakeholder Requirements Definition Process and the corresponding work products. The RE Process ontology, created from the application of ISP-OPL, is able to precisely define the concepts and relations for the requirements domain according to the ISO standards. These definitions, aligned to the core process definitions, serve as a common semantic basis for the related standards, contributing to their harmonization.

4.3 Experiment Analysis

From the resulting ontologies developed by the experiment participants, as well as by the application of questionnaires and interviews, we could collect relevant information about the usefulness of OPLs in general, and of ISP-OPL in particular.

Regarding the resulting ontologies, the seven ontology specifications were evaluated by the first two authors of this paper. The evaluation criteria include the correct use of the OPL, proper application of the patterns, and a sound documentation of the ontology, comprising the competency questions, OntoUML models, standards mapping, and other related information. The evaluation served to analyze each resulting ontology, but also to observe the OPL usefulness at all. In the following, we discuss some of the main findings, addressing the strengths, drawbacks and participants perceptions regarding ISP-OPL.

4.3.1 ISP-OPL Strengths

The main strengths perceived during the domain ontologies evaluation are discussed in the following.

Structural Similarity of the Conceptual Models: In a broad view, the first finding we could observe from the resulting domain ontologies regards the structural similarity between the OntoUML models. Since all the ontologies were created based on the OPL patterns, with the same general scope (addressing performed work units, work products handled by them, and stakeholder participations), it is clear the resemblance between the structure of each ontology, showing work units, work products and human resources in a similar way (all similar to Figure 13). This similarity also manifests itself in the ontology concepts and relations. We observed a similar granularity of the work units and work products, and compatible decisions for naming concepts, defining dependencies and setting work product participations. All these findings serve as evidences of compatibility between the domain ontologies, a desired result for the harmonization efforts.

Reuse of Competency Questions: Another interesting finding is the reuse of competency questions (CQs) from the OPL patterns. Once a DROP is chosen, its concepts and relations become part of the domain ontology, where they can be extended. For CQs, a very similar approach holds: once a DROP is chosen, its CQs can be extended for the domain ontology. For example, the Performed WP Composition pattern (see Table 1) has the following CQs: (i) Concerning their mereological structure, what are the possible types of performed work units?, and (ii) How is a performed work unit composed of other performed work units? When this pattern was applied to the Software Configuration Management (SCM) process, the following (extended) specific CQs were created: (i) What are the possible types of performed work units in the SCM process?, and (ii) How is the SCM process decomposed? This reuse helps the CQ definition, improving the productivity of the ontology engineering process.

Extraction of Concepts and Relations from the Standards: In order to develop the domain ontologies for the specific processes, each group had to analyze the related standards to elicit relevant concepts and relations. Once the domain ontology scope was established and the OPL was available, data extraction started by reading the standards and selecting the relevant concepts and relations. By using the OPL, the modelers could make a more productive extraction, looking only for those concepts and relations they need. For instance, some groups used different text markup to identify the sub-types of previously defined types (such as work units, work products and human resources) in the standards, speeding up the information extraction.

Enrichment of the Models: Standards are general by their nature and, sometimes, information is implicit or even absent. In ISO/IEC 12207, for example, although work units are well organized, there is little information about who (producers) performs them and which work products are handled by them. The supporting models used in the experiment (such as CMMI, MPS.BR and specific standards) allowed the participants to extract more information mainly about producers and work products. However, these concepts should be linked to the concepts and relations already identified in the ontology. Since the OPL patterns define the general organization of these elements, the patterns were used for linking the concepts extracted from different standards. For instance, in the ISO/IEC 12207 Risk Management process, nothing is said about who performs the Risk Management Planning activity, or about the main result it produces. The patterns Producer Participation Simplified and WP Creation require setting a producer performing this activity and a work product being created, respectively. Thus, looking for these
information, the ontology engineers identified in the IEEE Std 1540: 2001 [10] two important concepts for the Risk Management Process: the producer Manager and the composed work product Risk Management Plan. During the OPL application, for all processes, several producers and work products were identified and related to the proper work units. This shows the guidance provided by ISP-OPL, leading to more consistent models.

**Foundational Support**: As discussed above, ISP-OPL drives the definition of concepts and relations in the ontologies. However, it does not limit the ontology engineer. New domain-specific concepts, relations and axioms not considered in the OPL can be included in the ontology. Since ISP-OPL is aligned with the theories of the Unified Foundational Ontology (UFO), new concepts can be more easily integrated to the concepts extracted from the patterns by applying the same foundational theories underlying OntoUML. These notions help to create a more consistent model, going beyond the OPL support. For instance, some domain ontologies represented phases of Work Products, or roles assumed by an Information Item, or even the application of the role mixin foundational pattern [7]. This is the case, for instance, of the concept Configuration Item, which is not a regular Work Product, but generalizes the notion of different types of work products that have their configuration managed. Regarding this, it is important that the ontology engineers using ISP-OPL also knows the foundational theories underlying OntoUML, in order to correctly extend the patterns. For a discussion regarding the combined use of Foundational Ontology Patterns and Domain-Related Ontology Patterns, see [25].

### 4.3.2 ISP-OPL Drawbacks

During ontology evaluation, we have also identified the main mistakes made by the groups while developing ontologies using ISP-OPL. It is important to observe and analyze these problems in order to improve the OPL and the way to apply it. Following, we discuss the main mistakes and improvement points.

**Concepts Identification/Conciliation**: One of the most difficult tasks performed during the development of the ontologies about the specific processes was to extract information of the same process from different standards and to put them together. It is more a harmonization task than an ontology engineering one. ISP-OPL helps the identification of concepts by offering the general concepts and relations in its patterns. However, in different standards, some elements are not structured exactly in the same way. For example, similar work units in different standards can have different composing parts, and conciliating them was a common source of mistakes.

**Process Interaction**: The processes described in the standards generally refer to other processes. When these processes are represented as conceptual models, those interactions need to be made explicit. In this way, it is possible to identify more associated information, such as precedence, collaboration, use of work products, etc. Since ISP-OPL specializes work units according to their mereological decomposition (WUC / PWUC), and enables the representation of dependencies between them (WUD / PWUD), it is possible to represent the cases where a task “calls” a process, or tasks of another processes. This is a common situation, for example, in the processes Software Configuration Management, Software Maintenance, and Software Documentation Management. These processes are close related, being performed together in most of the cases. Making explicit process interactions helps to describe better the compatibility between processes. However, since each group addressed only one process, none of the groups had a comprehensive view of the process interactions. Thus, some integration work is still needed. Although there are similarities between the ontologies, other tasks, such as aligning the terms used and representing the identified interactions, are necessary. These tasks are important for building a complete Software Engineering ontology network [29], a useful artifact concerning the standards harmonization initiative.

**Wrong/Missing Classification**: Most of the concepts in the domain ontologies are extended from concepts of the applied patterns (except in few cases of domain specific concepts). Thus, each concept is classified as an extension of one or more previously defined concepts. Some of the domain ontologies presented mistakes in this classification. For instance, some simple tasks were classified as composite tasks (and vice-versa); some information items were classified as documents (and vice-versa); and some producers were classified as stakeholders. Another common mistake regards multiple classification. For example, when modeling a document composed of other work products, the new concept was classified only as a document, missing the composite work product classification. Even with the available OPL specification detailing the patterns, a more precise definition of each concept and relation is needed.

**Wrong/Missing Relation**: Most of the relations are also specializations of the ones in the pattern models. The main mistakes here regard the lack or wrong definition of certain relations. For instance, the dependence relation between work units was sometimes missed, and sometimes defined for tasks that are not really dependent. Another example of confusion occurred with the relations depicts and componentOf between work products. Finally, the relations create and use between work products and work units were sometimes confused and applied swapped.

**Insufficient Patterns in ISP-OPL**: Although in general ISP-OPL provided a good coverage to the software process domain, we identified at least two situations in which ISP-OPL did not attend the modeling needs of the participants, showing improvement opportunities:

1. As the WP Participation pattern defines (see Figure 11), a work product participation can be a creation, a change or a usage. It covers most of the situations, mainly for sequential processes. However, when iteration is considered, a work unit may create a work product in the first cycle, but can only use or change it in the next cycles, since it already exists. For example, in the RE Process ontology (see Figure 13), if the Requirement Recording task occurs in cycles, this task creates the Stakeholder Requirements Specification document only in the first iteration, and then, changes it by including / modifying / excluding its contents. Thus, ISP-OPL needs to consider other types of participation to allow modeling such situation. Thus, for the next version of ISP-OPL, we intend to add a new type of participation: produces, meaning that a work unit creates a work product if it does not exists, and then use or change it.

2. The second case involves the dependencies between work units. There is only one type of dependence, and it is not representative enough for all situations. For the next version of ISP-OPL we intend to include patterns for dealing with some of the Allen Relations [1], for example before and meet.
in order to gain more expressivity representing work unit dependencies.

4.3.3 Analysis of the Participants Perceptions

In the last phase of the experiment, questionnaires were applied and interviews were made with the participants. Our intention was to get the subjects’ perceptions about the use of ISP-OPL to build the domains ontologies. We have selected three main questions to discuss here:

(i) **Ease of Reuse:** How hard was to use ISP-OPL for creating a domain ontology?

(ii) **Productivity:** If you have a previous experience developing ontologies, do you consider that the OPL application contributed for the productivity in the ontology development process?

(iii) **Quality:** Do you consider that the OPL application contributed for the quality of the resulting ontology?

Regarding Ease of Reuse, as Figure 14 shows, 63% of the subjects considered it easy or very easy to use ISP-OPL for creating the domain ontology; 26% considered it neutral; and only 11% said that it was hard to use ISP-OPL for creating a domain ontology. Matching with the subjects’ profiles, 50% of the low experienced in conceptual modeling considered easy to use the OPL, against around 70% of the medium and high experienced. These numbers show that the use of ISP-OPL was considered easy in general, even for the subjects with less experience in conceptual modeling.

For analyzing Productivity, we had to consider only the participants who had previous experience in ontology development. 10 participants (53%) reported having previous experience in developing ontologies. All of them considered that the use of ISP-OPL speeded up the ontology development. 5 of them (50%) agree with this premise, and the other 5 (50%) totally agree (50%). Some participants emphasized that the guidance provided by ISP-OPL helped them to define the ontology scope and made the development process more intuitive.

Finally, concerning Quality, when asked if ISP-OPL application contributed for the quality of the resulting ontology, all the 19 subjects agreed (37%) or totally agreed (63%). Some subjects pointed out that ISP-OPL helped them to capture the main concepts of the domain, to reduce errors, and to create a well-founded ontology.

4.3.4 Threats to the Validity of the Experiment

We have identified some limitations and validity threats to our experiment. Firstly, although the participants had similar formation (in Computer Science area), they were students with different experience levels in conceptual modeling and ontology development. Along the course, the participants studied the content necessary to execute the proposed activity. However, the results might be affected by the different experience levels. Secondly, the participants had also different background regarding the sub-domains chosen for building the ontologies. Some of the groups knew well the process being modeled, while others had a first contact with the process being modeled during the activity. Thirdly, the activity was done as a homework, and, although the deadline was the same for all groups, some groups might have spent much more time in the activity than others. Fourthly, the number of participants was small, and thus we had not a representative sample. Because of that, we could not apply statistical hypotheses tests.

5. RELATED WORK

Regarding works on software process standards harmonization, Pardo and colleagues [22, 21] have developed a framework for harmonizing multiple-models using ontologies. Their concerns are the same of ours, about standards interoperability. However, whilst our work focuses on the establishment of ontologies for the domains dealt by the standards, the ontology proposed by Pardo et al. (H2mO – Ontology for the Harmonization of multiple-models) focuses on the harmonization domain itself. The main goal of H2mO is the assignment of a formal and clear definition of the most widely used techniques, methods and related terms in harmonization of multiple models [22]. It copes with concepts such as Harmonization, Integration and Comparison to represent the mappings between models. Although H2mO contemplates more specific concepts such as Process, Activity and Resource, they are used only to map the information acquired from the models. Another important difference is about the application focus. H2mO is used for harmonizing different models applied by an organization. The ontology is used to perform comparison operations (intersection, union, difference and complement) between models, resulting in information about the related models, which helps their integrated adoption by organizations. The focus of ISP-OPL is to promote harmonization on the standards level. The main idea is to represent the knowledge about the software process domain in a reusable way to create standard domain ontologies (SDOs), establishing a semantic base of harmonized concepts to guide standards creation and revision.

Concerning ontology patterns, OPL is a new concept, established in [5], and there are few works published. The first one was the Software Process OPL [5], built from a mature Software Process core ontology grounded in UFO [4]. ISP-OPL was built from the ontological analysis of the ISO/IEC 24744 metamodel [24] in the light of UFO, packaging the resulting ontology fragments into patterns to compose the OPL. This process of patterns definition was inspired by the patterns arrangement of SP-OPL, given that both these languages address the same underlying domain. SP-OPL is for general use of software processes and has patterns regarding organizational standard process, software and hardware resources and procedures. In one hand, ISP-OPL has been designed to meet the ISO harmonization initiative needs. Thus, due to the initial priorities of the ISO initiative, these aspects were not included yet in ISP-OPL. On the other hand, ISP-OPL has established finer-grained patterns, and has more specialized human resource patterns. In particular, it details the composition and nature of work products, as well as its participations in work units, and applies a terminology and structure aligned to ISO SC7 standards.
Another related OPL is the one for the Enterprise domain (E-OPL) [6]. Although constructed in a domain that is different from that of ISP-OPL, the ontology reuse intents motivating E-OPL are the same. Moreover, there is an intersection between the software process and enterprise domains regarding human resources. Once we have some analogous requirements, certain E-OPL pattern solutions motivated ISP-OPL patterns. Thus, the E-OPL patterns concerning employment, team definition and human resource membership have inspired the ISP-OPL corresponding patterns, namely HR Employment, Organizational Team Definition, Project Team Definition, Team Role Definition, Team Membership with Role, and Team Membership Simplified, which used a similar solution adapted to the new needs and terminology.

Finally, the ISO ontological framework [9] is also related to this work. The framework does not consider ontology patterns, but provides two mechanisms for ontology derivation. The first one is based on discarding ontology parts. The idea is that the elements in the definitional ontologies are interconnected and the relations between two concepts may have a minimal cardinality of zero. This means that, for any occurrence of the concept on one side of the relation, it may have no occurrence on the other side. In this case, the concept in the opposite side (and the relation) could be discarded in a derived ontology [9]. We think discarding concepts and relations is not a matter of cardinalities, but it is related to the ontology scope and the domain being modeled. Thus, for example, in ISP-OPL, the pattern PPP associates a Performed Process to exactly one (1..1) Project. If the resulting ontology does not need this relation, or even the concept, the ontology engineer can choose not to use PPP. In this case, independently of the cardinality values, the relation is not established.

A second mechanism used in the ISO ontological framework is the specialization of concepts in the resulting ontology. This mechanism is used there basically in the same way that it is used in OPLs [5], except for its applicability. The difference is that the framework derivation mechanisms are dealing with a whole model, and the OPL solution treats it in a modular way, reusing each of the patterns needed, following the guidance provided by the language.

6. FINAL CONSIDERATIONS

The ISO harmonization efforts have focused on the development of a layered ontological framework, wherein the semantics described by the higher levels (DEO and CDOs) can be propagated to the other levels (SDOs) [9]. In this context, ontology patterns are a promising approach, since they favor reuse of encoded experiences and good practices [23]. Additionally, Ontology Pattern Languages (OPLs) have the potential to amplify the benefits of ontology patterns, by providing guidance through the ontology derivation process [5].

Our main goal is to provide to the ISO framework features of OPLs, guaranteeing an ontologically consistent and standard-adherent basis that can be used to derive interoperable ontologies for ISO standards in a rich reuse process. In order to pursue this goal, we have developed ISP-OPL, the ISO-based Software Process OPL. This OPL is based on ISO recognized software process standards, such as ISO/IEC 24744 and ISO/IEC 12207, and is grounded in the Unified Foundational Ontology (UFO).

We expect that ISP-OPL can be applied for modeling the several software process domains related to ISO SC7. For evaluating ISP-OPL usefulness and applicability, we have conducted an experiment developing seven software process related domain ontologies, using information of selected ISO and other SE standards. Amongst the several findings and improvement points, we could collect evidences to confirm the previously reported practical benefits of the use of OPLs [5, 6]. We have experienced that the guidance provided by the patterns language in the process of developing domain ontologies resulted in an increased productivity in the development process, and a reduction of inconsistence problems in the produced models. Moreover, the resulting models showed to be more compatible with each other. The findings collected in the experiment are fundamental for advancing ISP-OPL in different perspectives. Technically, the pattern models and descriptions can be improved. In terms of usability, many improvements are planned to make easier the application of ISP-OPL. Regarding the harmonization efforts, the domain ontologies developed consist in a rich material to be integrated as an ontology network [29], and used as base for the development of ontologies for other sub-domains and standards. As the main difficulties faced in the experiment, we can quote the matching of the information from different standards, and the effort for integrating the voluminous number of concepts and relations. Some of these issues are helping us to improve ISP-OPL; others can be used to improve the standards themselves, as inputs for the harmonization efforts.

As an ongoing future work, we are improving ISP-OPL with the experiment feedbacks, and we intend to enlarge ISP-OPL by adding new patterns. Our next steps include working on patterns to deal with techniques, software and hardware resources, and the planning of work products. We also plan to apply ISP-OPL for other relevant software standardized domains, increasing the domain representation coverage. With the new patterns and larger coverage, we expect that ISP-OPL can be accepted as an effective solution for the ISO Harmonization Initiative.

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8. REFERENCES


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Towards Persuasive Social Recommendation: Knowledge Model

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ABSTRACT
The exponential growth of social networks makes fingerprint let by users on the Internet a great source of information, with data about their preferences, needs, goals, profile and social environment. These data are distributed across different sources of information (social networks, blogs, databases, etc.) that may contain inconsistencies and their accuracy is uncertain. Paradoxically, this unprecedented availability of heterogeneous data has meant that users have more information available than they actually are able to process and understand to extract useful knowledge from it. Therefore, new tools that help users in their decision-making processes within the network (e.g. which friends to contact with or which products to consume) are needed. In this paper, we show how we have used a graph-based model to extract and model data and transform it in valuable knowledge to develop a persuasive social recommendation system.

Categories and Subject Descriptors
I.2 [ARTIFICIAL INTELLIGENCE]: Distributed Artificial Intelligence
H.3 [INFORMATION STORAGE AND RETRIEVAL]: Miscellaneous

General Terms
Algorithms

Keywords
recommender systems, data integration, social networks

1. INTRODUCTION

Over the last few years, social networks have changed the way users perform many of their daily activities on the Internet. Concretely, direct interactions between users with different final goals have won ground on mere search and navigation activities over stored information. Therefore, users have evolved from being mere consumers of information to real producers. In Spain, for instance, 93% of Internet users access social networks daily; 2 out of 3 take into account the recommendations of other users to make decisions (on products, treatments, entertainment, etc.); and of these, 69% gives a lot or some credibility to what their friends or acquaintances say in a social network.

However, the increasing number of users and information generated, the heterogeneity of the users themselves, their unpredictable behavior, and the dynamism of the network structure (members joining and leaving the network at their will, consequently evolving the network’s structure), make users to deal with a high degree of uncertainty when choosing who to interact with or what information to consume [1]. In order to decrease this uncertainty, tools that help users in their decision-making processes within the network are required. A promising solution is the use of recommendation systems [2, 3], which are capable of performing effective recommendations to help users to make appropriate decisions.

Nevertheless, traditional recommender systems base their recommendations on quantitative measures of similarity between the user’s preferences and the current items to recommend (i.e. content-based recommenders [9]), between the user’s profile and the profile of other users with similar preferences (i.e. collaborative filtering recommenders [10]) and on combinations of both (i.e. hybrid recommenders [11]). However, [12] has stated the inability of current recommender systems to use the large amount of qualitative data available online to empower recommendations. Usually, recommender systems do not provide an explanation about the reasoning process that has been followed to come up with specific recommendations. Recommendations tend to come directly from the recommendation algorithm that runs the website and not from the acquaintances that a user

1Copyright is held by the authors. This work is based on an earlier work: SAC’15 Proceedings of the 2015 ACM Symposium on Applied Computing, Copyright 2015 ACM 978-1-4503-3196-8. http://dx.doi.org/10.1145/2695664.2695732.
has in his/her social network. However, this does not follow current trends on the Web, where discovering is becoming social and recommendations could be expected to come directly from acquaintances in a decentralised way. Moreover, people trust recommendations more when the engine can provide reasons for them [13] and when the recommendation comes from an acquaintance. Thus, what is understood as a good recommendation is changing from the one that minimises some error evaluation to the one that is really able to persuade people and make them happier.

Another problem with traditional recommendation approaches is that they barely take advantage of the huge amount of information underlying the network structure. Different pieces and sources of information must be treated in an uniformed way in order to improve the recommendation processes in social networks. This requires making projections between the vocabularies used as patterns in different data sources and merging data (instances) of different sources. There exists mechanisms in RDF Schema and OWL to express such relationships between terms of vocabularies and to perform transformations between schemes easily. There are also work reported in the literature about how to generate these alignments in a more or less automatic way [4, 5]. The main challenge in data fusion is the resolution of conflicts when different values for the same property of an object are obtained. There exists works in this line in the database research community [6], and the efforts on reconciliation of identities in the Web research community is also growing [7].

Following this approach, in this paper we propose the employment of graph databases as a knowledge model to integrate domain-specific and social data obtained from social networks, and use it to perform persuasive recommendations. Graph databases focus on the structure of the data, storing information as a network [8]. Data on social networks are increasingly interlinked and connected, and graph-based models allow to represent billions of nodes and relationships. Therefore, in contrast with relational and other NoSQL database models, graph-based databases have demonstrated their improved performance when dealing with connected data [8].

Our ultimate goal is to exploit the benefits of this model and use this valuable information to generate recommendations in a persuasive social recommendation system. Thus, the information stored in our graph-based models will be transformed in recommendations enhanced with explanations and arguments, able to persuade the user about the actual suitability of the recommendation that he/she has received.

The rest of the paper is structured as follow: section 2 presents a prototype of our persuasive social recommendation system; section 3 shows the proposed graph-based knowledge model; section 4 reviews related work; and, finally, conclusions are explained in section 5.

2. TOWARDS PERSUASIVE SOCIAL RECOMMENDATION

To develop and validate our knowledge model, we have focused our research on the domain of recipes recommendation. As pointed out later on section 4, there is a notable increasing demand of recommender systems to improve the health habits of their users and to help users to plan their meals when they have to observe certain dietary restrictions. More than 17 million Europeans suffer from some form of food allergy, according to the European Academy of Allergy and Clinical Immunology (EAACI), and this number is expected to increase in forthcoming years.

Currently, we are developing a prototype, based on our website receteame.com, which recommends recipes for its users. receteame.com2 is a persuasive social recommendation system to make personalized recommendations about recipes to its users. The system retrieves recipes from the Internet and automatically calculates their nutritional information and dietary restrictions to use this information to make recommendations. We are also developing an intelligent algorithm (based on argumentation techniques and social network analysis) to learn the tastes and needs of each user and recommend fully customized recipes from two main sources of information: the votes that users give to each recipe, and, the activity of the user and friends in Facebook. Each time a registered user will search for a recommendation, the algorithm will receive a recipe recommendation query, including parameters describing the user profile (preferences and tastes, dietary restrictions, personal data, etc.) and the context of the query (e.g. if the user is looking for a main course of for a particular ingredient, the number of dinner guests, etc.). With this information, the algorithm will perform two main searches to select a potential set of recipes to recommend to the user. On the one hand, the algorithm will follow a content-based recommendation approach to generate a list of recipes that match the query. However, note that the accuracy of recommendations generated by this process completely relies on the amount and accuracy of previous votes that the user made to other recipes with similar characteristics. Therefore, it is highly influenced by the cold start problem (i.e. the performance of content-based recommenders is poor with new users that have not yet rated a sufficient amount of recipes) and the drawbacks of applying traditional recommendation approaches on large social networks (i.e. issues related with computational costs of getting an accurate recommendation, and loss of the big amount of related social information available in the network). To overcome these problems, the algorithm will perform an alternative search that will follow a social recommendation approach.

On the other hand, the algorithm will select a set of users of the system and spread the query to obtain recommendations from these users. This set will contain the set of friends of the target user, and if necessary, a randomly selected set of users to avoid the cold start problem when the target user is new on the system and still does not have an adequate number of friends. Each user that has received the query will select a set of recipes that match the original query from his own set of known recipes (those voted by this user). Then, for each user, this part of the algorithm will generate an ordered list of recipes to recommend according to two criteria: the preferences of the user that is being asked for recommendations, for instance, taking into account the votes of the user; and the preferences of the target user, for instance, taking into account the votes of the target user to a recipe (if any). Note that this process will be performed automatically, without the direct intervention of the actual users, but the algorithm will be in charge of retrieving and

2http://www.receteame.com; http://buscador.receteame.com
managing the necessary information to perform these tasks and simulate the interaction between users.

With the full set of recommended recipes from other users, the algorithm will make an overall ranking of recipes employing four social criteria parameters: 1) the trust on the user who had recommended a recipe from the point of view of the target user and his friends. This parameter will be calculated by using a direct trust evaluation between these two users, and, if any, aggregating the trust evaluations of the friends of the target user that are also friends of the user that made the recommendation; 2) the reputation of the user who had recommended a recipe. This is a global parameter that will be calculated by computing the average trust regarding all recommendations made by one user to his friends; 3) the strength of the friendship between the target user and the user that had recommended the recipe. This parameter will be calculated by using several predictive friendship variables [15] and will depend on the activity of the target user on the social network where the algorithm operates (Facebook for now); and 4) the similarity between the target user and the recommender user in terms of their preferences. The result of this process will be a unique and ordered list of recipes to recommend to the target user. Finally, the algorithm will mix the recommendations that has obtained from both searches, assigning weights to bound content-based and social-based recommendations, and will select the best recommendation to propose. This process will also include an internal agreement procedure based on argumentation techniques, which will allows the algorithm to propose first those recommendations for which it will be able to generate better justifications [16]. This justifications will be arguments to explain the user the suitability of the recommendation provided, showing pieces of information that could persuade him/her to accept and put into practice such recommendation (e.g. to show a celiac user that enjoys chocolate cakes that the recommended recipe to cook a chocolate muffin that has no gluten and is specially recommended by a trusted user in his/her social network).

As pointed out before, this system is currently under development and we focus on this paper on the knowledge model that we are using to extract and model our data to transform it in valuable knowledge for our persuasive social recommendation system.

3. GRAPH-BASED KNOWLEDGE MODEL FOR PERSUASIVE SOCIAL RECOMMENDATION

In this section we show how information is retrieved and integrated into a fast and highly available graph-based database that allows us to perform the recommendation process in an efficient and effective way. For our recommendation process we need to retrieve two types of data: social data from the users, and domain-specific data. As domain-specific knowledge, we use a big amount of recipes (over 10,000), with nutritional information about their health issues, diseases for which they are encouraged and discouraged, nutrients of each ingredient and their relationships with health and dietary labels. In what follows, we present how we have retrieved both social information and recipes information and how we represent this data in our graph-based model.

Due to the users heterogeneity and dynamism, we have to manage an enormous quantity of data that is constantly generated in an efficient way. Thus, the traditional databases main drawback (i.e. the data consistency (ACID\(^3\) philosophy)) makes them inappropriate for our purposes. In addition, in an environment as interrelated as a social network, it becomes necessary to store the semantics that is underneath the interaction of the users (i.e. we are more interested in the relationships than in the content). The need to include new information in the database that may be related with hundreds of already stored data (e.g. users) will imply an excessive computational cost, and this is precisely one of the features for which the NOSQL databases (guided by BASE\(^4\) principles) show their potential. Concretely, in our domain the entities can be interrelated among them, with a high growth and dynamism in such relations. Therefore, among the different types of NOSQL databases, we will work with graph databases. This type of databases are highly scalable and close to the natural structure of the data.

3.1 Social Information

In this section, we present the knowledge model that we use to store and manage the information about the user who wants to receive recipe recommendations by using the persuasive social recommender that we are developing. For this task, the site receeteame.com, provides us an interface to interact with the user.

In this site, the user could register or log in with the user’s Facebook account. The Facebook registration process is carried out by means of OAuth 2.0 protocol\(^5\), that is widely used on social networks and applications that work with them. This method facilitates the access to HTTP services in a restricted way (setting limitations to the specific pieces of the user’s Facebook information that the system is able to access). These limitations are imposed by the user, who provides permissions to the application in the register phase (i.e. the application requests some permissions to access to the user’s mail account, birthday, or friends list, among others). This is a sensitive step of the process, due to the reluctance of users when they are requested for granting permissions related to their personal data. For this reason, we made available online a demo of our system and achieved more than 2000 registered users to test how users react to our permissions request. Our tests showed successful results, getting those permissions in over the 80% of the cases (getting access to very sensitive information such as the inbox messages, shared links and tagged photos).

Once the registration process has finished by means of the Facebook account, the application gets a token that identifies the relationship between the user and the application. With this token, the application can obtain the user’s node that is stored in the Facebook’s databases. This node enables the application to obtain the information about the user’s activities in the social network, such as “likes”, comments or tags. Only the information related with the user’s interactions in the social network is stored in the application’s database (we anonymize other personal data to observe data protection laws, and the contents that the user has in the user’s account, such as messages or posts, are not stored).

Figure 1 shows the graph-based model with the information about the user that we are able to obtained with this

\(3\)Atomicity, Consistency, Isolation and Durability

\(4\)Basically Available, Soft state, Eventual consistency

\(5\)http://oauth.net/2/
3.2 Domain Information

In this section, we present the knowledge model that we use to store and manage the information about the recipes that our system will recommend. Making recipe recommendations requires to have a big database of valid recipes that may result interesting to users. The bigger the database is, the most varied and accurate recommendations can be delivered to users. Recommending recipes also presents a special characteristic; although people may be interested in world wide recipe discovering, they usually tend to be interested in local cuisine that uses products and ingredients that they can easily obtain. This is also the rationale of the local food movement, which tries to reduce the distance between food producers and consumers and achieve a more sustainable food chain. Other important feature when recommending recipes are cooking techniques, since users tend to be interested in cooking what they can afford. For instance, it makes no sense to propose a recipe that requires a tandoor oven (a cylindrical clay or metal oven used in Southern, Central and Western Asia, as well as in the Caucasus) to users from Western Europe, since they have not easy access to this kind of cooking appliances.

These considerations have guided us to build a recipe database focused in a unique country (Spain), with Mediterranean eating habits and a very rich cooking tradition. Spanish gastronomy is varied and rich, making use of lots of fresh ingredients like vegetables, fruit, fresh fish and shellfish, and ingredients that are country-specific while famous, like olive oil or Iberic ham. These ingredients are accessible everywhere in Spain but are not as common outside the country.

Then, there are three ways of building a good recipe database that accomplishes these characteristics: to hire nutritionists and chefs to write it, which is too expensive, to let users to upload their own recipes, which is too slow, and to crawl the web looking for the recipes. The latter was the method followed in this work.

In order to locate semantically correct recipes we made use of microformats [14]. Microformats (\(\mu F\)) is a semantic markup language that extends HTML with semantic tags that allow web pages to be processed automatically and extract data that contains semantic information intended for end-users. Two of the most known microformats for recipes are h-recipe and Schema.org Recipe. Both are very similar and use classes or itemprops to tag content. Some tagable information for recipes is preparation time, recipe instructions, description, or ingredients. Recipe microformats have also nutritional information that can be useful (when present) to classify recipes for users with special requirements. Figure 2 shows the information that we have retrieved and stored in our graph database.

The non-repeatable information is stored in the Recipe node (e.g. the recipe title, description, image, instructions, preparation time, servings, etc). On the other hand, all the information that may be useful to be represented as relationships has been modeled in separated nodes connected by relationships (e.g. the list of ingredients, health and diet labels, tags, difficulty, etc). With this graph representation it is easy (and quick) to find recipes that share a set of ingredients, or that are appropriate for a specific allergy (looking at the encouraged and discouraged diseases relationships or the health labels). The nutritional information is also represented in this graph, connecting all the nutrients contained in an ingredient with the health labels and diet labels which are related to. This nutrient information has been extracted from the United States Department of Agriculture, who has published a National Nutrient Database for Standard Reference\(^6\).

Our crawling algorithm based on microformats has gen-

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\(^6\)http://ndb.nal.usda.gov/
erated a database of more than 10000 recipes that can be extended dynamically. The database growth rate is limited by the poor number of websites that use microformats (and even more limited if we focus only in recipes from a specific country or region). Microformats are very extended for calendar events (h-event) and people information (h-card), but are still not widely adopted to represent information from other prepared models, like h-recipe, h-product, h-item, etc, or the schema.org standards like Restaurant, Review, Product or Health.

3.3 Full Knowledge Model

Once explained how data have been obtained and organized following a graph-based model, the next step consists on the integration of both social and recipe information into a full graph-based knowledge model. Figure 3 shows how this integration has been defined. The use of the graph-based model allows a natural fusion of the obtained information, just adding the necessary relationships among existing nodes of both social and domain-specific data. Most relationships are between the User nodes and the Recipe nodes. These relationships between nodes mainly represent events that have occurred in the system. The relationship VIEWED represents that a user has viewed a recipe at a specific date. The same applies for the RATED relationship, which means that a recipe has been rated by a user with the rating rate. There is another relationship between Recipe and User but, this time, in the opposite direction. This relationship represents the event that a recipe was recommended to a user at a specific date. Finally there are relationships that do not represent events but semantic information, such as a disease that a user suffers, a diet label the user is interested in (i.e. HIGH_PROTEIN), or the user that has published a recipe.

One of the main advantages of using this approach is that the produced overload in the model due to the increase of the number of nodes is considered as negligible comparing with traditional approaches. Therefore, scalability is not a problem. One important feature of the proposed model is that there exists a clear imbalance between the nodes needed to represent the social data and the recipe data. After the extraction process, the number of recipes were around 10000 and the number of nodes needed to store the social information of users were around hundred thousands. Moreover, the dynamism of this kind of information can produce an exponential evolution. Nevertheless, our persuasive social recommendation prototype perfectly supports these orders of magnitude.

Another important issue is the information retrieval process for recommendation purposes. In this sense, the declarative language supported by this kind of models and the optimized storage facilitates a fast retrieval of the nodes and their relationships. To show the expressivity of the query language, empowered by this graph-based technology, let us propose an example where we want to get a recommendation based on the relationships between two users. Let us assume that we want to make a recommendation to a user that has a disease (i.e. an allergy). Also, let us assume that people who was born in the same town share eating habits. With all this information we are going to search for two users that share a disease, who were born in the same hometown and who have a tie strength (a friendship value) calculated between them, and get a recipe that was rated by this second user. Then, in the same query, we apply a filter to get only users with a high tie strength (more than 4.0 in this example). We also filter all the recipes that were already rated by the target user of the recommendation, in order to not recommend a recipe that the user already knows. Finally, we also filter all the recipes that are discouraged for any of the diseases that the target user has (not only the disease shared with the other user), because we do not want to recommend a recipe that may be dangerous for our user.

This query example is shown in Listing 1. Having this information represented in a unique graph empowers us with the ability to create recommendations with relatively simple queries, as shown in this example.

Note that to perform such a query, our knowledge model must accurately store links between recipes and those allergies or food intolerances that produce their ingredients. Therefore, we need to classify each ingredient of each recipe as appropriate or not for each allergy or intolerance that we want to take into account in our recommendation process. The list of allergies and intolerances that we have considered is the one proposed by the 1169/2011 EU regulation, which are:

- Cereals containing gluten
- Crustaceans and shellfish based products
- Eggs and egg-based products
- Fish and fish-based products
- Peanuts and peanut-based products
- Soybeans and soy products
- Milk and products thereof (including lactose)
- Nuts and derivatives
- Celery and celery-based products
- Mustard and mustard-based products
- Sesame seeds and sesame seeds based products
- Sulphur dioxide and sulfites at concentrations above 10 mg/l or 10 mg/Kg
- Lupin and lupin-based products

Figure 3. Integration graph model
• Mollusks and mollusks-based products

Furthermore, we have created a classifier to detect the presence of alcohol and another for the presence of fructose (ones of the most common food allergies). Most of our classified ingredients appear in the National Nutrient Database for Standard Reference (USDA), which provides us information about their nutrients that we can use to detect the allergies and food intolerances that they produce. However, there are Spanish specific ingredients that do not appear in this database, and among the data available for each ingredient there is not always enough information to know whether they are appropriate or not for an intolerance or allergy. For example, in the case of lactose, only 1530 out of the 8000 ingredients of the USDA database have information about this nutrient. Therefore, to classify the remaining ingredients a machine learning algorithm based on decision trees was used to determine if an ingredient contains a nutrient or not (lactose, for instance). This process was repeated for each intolerance or allergy that we wanted to take into account. As input to the decision tree we used the set of nutrients labelled in the USDA entry for the ingredient, the name of the ingredient and the Food Group. Then, we used the BigML\(^7\) technology to train a model for every food intolerance and allergy, using 80% of the data for training and 20% for test. Figure 4 shows the model generated to detect lactose in the ingredients.

\(^7\)https://bigml.com

Figure 4. BigML model to detect lactose in an ingredient

Figure 5. Classification results obtained to predict the appearance of lactose in an ingredient

The results obtained are promising, getting between 89% and 99% accuracy in classification (these variations depend both on the initial data set size for training and on the relationship between the different nutrients of an ingredient and the presence of the specific nutrient to be detected). However, we are continuously improving our model, since allergies detection and classification must be treated with great rigor because of its serious implications on the health of users.

4. RELATED WORK

In addition to the drawbacks of traditional recommender systems, pointed out in section 1, online recommender systems suffer from problems inherent to their use in complex social networks, where the number of users and/or items to recommend can be very high. In the case of collaborative filtering, for instance, the process for comparing two users with the aim of extracting their similarity requires that they have qualified the same objects, which can be unrealistic in large social networks. Another major weakness of online recommender systems is their trustworthiness. In an open network with a large number of users is impossible to ensure that all views expressed are true opinions of users and there

后果

MATCH (user1:User)-[:TIE_STRENGTH]->(user2:User),
(user1)-[:HAS_DISEASE]->(diseases:Disease)
(user1)-[:HAS_DISEASE]-(user2),
(user1)-[:BORN_IN]->(hometown)<-[:BORN_IN]-(user2),
(user2)-[:RATED]->(recipe:Recipe)
WHERE tie > 4.0 AND
NOT (user1)-[:RATED]->(recipe) AND
NOT (recipe)-[:DISCOURAGED_FOR]->(diseases)
RETURN recipe
ORDER BY rated.rate DESC LIMIT 1

Listing 1. Example Query
Moreover, over the last years we can find in the literature some recipe recommendation systems [23, 25, 22, 24], which illustrate the increasing demand for this type of systems, specially when planning special meals that must observe dietary restrictions and group meals. However these proposals are not conceived as online recipe recommender systems and do not follow a social recommendation approach [21].

5. CONCLUSIONS

This work presents a graph-based knowledge model for persuasive social recommendation. The system is embedded in the web application receteame.com that recommends recipes that fit the preferences and dietary restrictions of its users, currently under development. For the implementation of this system, we have used a graph database which is highly scalable and close to the natural structure of the recipe data and users’ social data that we work with. This approach is highly flexible and scalable, and the expected overload in the model due to the high dynamism of recipes and social information on the web (which produces a quick increase on the number of nodes) is considered as negligible comparing with more traditional approaches. In addition, the declarative language supported by our model and the optimized storage facilitate a fast storage and retrieval of the nodes and their relationships in the recommendation process. As current work, we are working on making the recommendation process faster and accurate and on designing an argumentation framework to generate arguments to justify the recommendations. We will also gradually manage more comprehensive dietary restrictions to take into account new diseases and intolerances in the recommendation process. Furthermore, receteame.com will be able to recommend full menus in the future, such as a weekly menu for a family that fits the preferences of all members, or a menu for a dinner with friends where the guest can cook something with the confidence that it will like to all guests and fit their dietary restrictions.

Acknowledgment

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### ABOUT THE AUTHORS:

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