INTENSIFYING THE DEVELOPMENT OF WEB-BASED VIRTUAL MUSEUMS FOR E-LEARNING DOMAIN

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ABSTRACT
Museums are a large repository of memories of History, Art and Humanity that may become an important teaching-learning tool on the Web. Although there are many museums on the Web, the effort for building and maintaining them can directly impact the adopting for learning purposes. This article presents an approach to intensify the building of web-based virtual museums to be used as an e-learning tool. Regarding that the web-based virtual museums are a specific domain, we have developed the e-MuseumSPL - a software product line to support the building of virtual museums based on software reuse principles. To validate the proposal was implemented - by two groups of developers - two versions of museums. Based on the outcomes, we outlined some reflections about: (i) the advantages and disadvantages of using the approach in the developers’ point of view; and (ii) the feedback of ten end-users (students) about their satisfaction on interacting with the museums.

KEYWORDS
Web-based virtual museum; e-learning; software reuse; web software architecture

1. INTRODUCTION

The virtual museums can be considered an important tool in different degrees of education process: (1) formal - following the school curriculum guidelines, (2) informal - based on the parents’ and society’s interventions, and (3) non-formal - occurs outside of the school, but it is directly related to it (Smith, 2002). When a person visits a museum (real or virtual), s/he deeps into the historical facts and can link them to the present, developing meaningful experiences with significant contribution in all the perspectives: formal, informal, and non-formal. In the e-learning perspective, the virtual museums bring the flexibility to extend and construct tools to meeting different features of educational context. Besides this, an e-learning tool allows the teacher to build learning scenarios to enrich his/her classes.

The exhibitions of museums artworks supply directly to the development of culture and education, justifying its importance for the education and culture of humanity. Some works report reviews and experiences that highlight the importance of museums in the teaching-learning process (Sarah, Prihatmanto and Rusmin, 2012; Berry, Sheard and Quartly, 2011). Vavoula et al (2009) addresses an experiment in the MyArtSpace project in which mobile devices are used by children during a museum visit. An application on the smartphone guided children with multimedia presentations related to exhibits. During the visit children could upload photos and videos that were recorded into a website. When they returned to the classroom they were able to share and exchange the acquired knowledge and the photos and videos with one another. On the other side, Arends et al. (2009) presents an exploratory study of art museum websites and their web 2.0 features. In the work, the authors state the characteristics on the dimensions of exploring artwork, using for educative purposes, and announcement of events and discussions. For educative purposes the study points out the use of sharing and annotations about artworks and the games to motivate the visitors in testing their knowledge.

Although making available the virtual museums as web-based tools improve the access for them, it is necessary to offer approaches for enhancing the development and maintenance of these tools. Despite of the Web technologies, as HTML, could be enough for constructing virtual museums, the implementation of reuse and maintenance of coding will demand arduous efforts on the designing of them. Concerning the focus on (1)
the effort to developing and maintenance of virtual museums as a web-based tool; and (2) that the virtual museums represents a specific domain of product families, the Software Product Lines (SPL) may be an alternative to promote the quality, productivity, and the reuse of the applications developed for specific domains (Chimalakonda, and K. Nori, 2012; Falvo et al 2014). A SPL may supply the process of software construction with concepts and technical tools for developing products in a systematic way in order to generate a family of products. The main proposition is the building of products based on the reuse of an infrastructure that includes: software architecture, components, design patterns and planning methods. Differently of an oriented-object reuse in which the reuse of components are the main point, an SPL approach is driven by a development oriented by the software architecture; and the structure are composed by unit tests and documentations that easily promote the reuse and the automatically generation of code.

To the effectiveness of the reuse, the software components are developed concerning the similarities (common or generic points), called core assets, and the variabilities (which must be defined and managed by a specific instance) in a family of products. The traditional methodology for SPL construction is divided into two steps: Domain Engineering (DE) - activities to provide that solution driven by systematic tasks for the identification and organization of the knowledge domain; Application Engineering (AE) in which the applications are built based on the reuse of the core artifacts previously developed in DE (Clements and Northrop, 2002). Within the advantages of adopting SPL to developing web-based e-learning tools, some works explore different approaches: the use of Model-Driven Development (MDD) (Zhou et al., 2008; Cong et al., 2010), m-learning applications (Falvo et al, 2014), interactive applications (Dalmon et al, 2012), and a SPL for teaching dialects in India (Chimalakonda and Nori, 2012). All the authors of these works highlighted that the SPL adoption was important not only to improving the productivity, reuse and quality of the product, but also the satisfaction of developers and end-users with products generated by the respective SPL.

Based on two statements – (i) the value that web-based virtual museums can bring for e-learning area, and (ii) the use of SPL fundamentals to support the creation of virtual museums - this paper has the goal to present an approach that aims to intensify the building of web-based virtual museums for the e-learning domain. Regarding that we were dealing with a specific domain, we have developed the e-MuseumSPL - a software product line to support the construction of web-based virtual museums based on strong software reuse principles. The approach supplies the developers with a web-oriented architecture solution which focus on the reuse, quality and productivity of software development. The 3D environments are out of the scope of the e-MuseumSPL whose focuses on the museum artwork and not on the immersion in historical surrounding (Karoulis, Sylaiou and White, 2006; Marty and Twidale, 2004).

The remainder of this paper is organized as follows: Section 2 presents the approach e-MuseumSPL and outlines on how the domain of virtual museums was explored for the conception of it; Section 3 reports the conduction and the outcomes of the approach experimentation in both viewpoints: by the developers and by the students (end-users); and finally Section 4 summarizes the conclusions and the directions for further works.

2. THE APPROACH: CONCEPTION, DESIGN AND IMPLEMENTATION

The development of a SPL starts in the DE step aiming at the identification and investigation of specific domain aspects in order to produce the SPL based on their similarities and variabilities. In this work, we followed the traditional activities of DE: (i) study and analysis of the domain aspects; (ii) the specification of the web-based and domain-based architecture; and (iii) the development of the core assets of the SPL (Clements and Northrop, 2002). First, two sub-activities were carried out to support the activity (i): (a) a comparative study of six web-based virtual museums, and (b) an exploratory activity with potential end-users for checking the acceptance of the features of the museum gathered from sub-activity (a).

The comparative study (a) aimed to raise the key features usually found in virtual museums that go beyond the artwork exposition, and to verify aspects related to user interaction (interaction channels). Driving by the statements of Karoulis, Sylaiou and White (2006) and Marty and Twidale (2004) - who report that the use of excessive elements of interaction may cause troubles into the end-users attention on the artworks - the study was carried out in six famous web-based virtual museums (Van Gogh, Louvre, British, Egyptian, Salvador Dali, and Minas Conspiracy); five of them were selected because of their popularity and of their free access; and the Minas Conspiracy Museum was included for its relevance to the History of our country. The study revealed to us the common features (present in most of the products of the family) and the variabilities (found in one or in some products of the family) which restate the viability of developing the SPL in virtual museum domain.
In order to verify the acceptance of the features and the potential of the web-based virtual museum for teaching and learning purposes, an exploratory activity (b) was conducted in two steps. First, with the participation of two museum experts and four History teachers, a brainstorming was carried out, allowing the identification of the museum system actors and their respective educational activities into the virtual museum. The museum expert actor has basic activities the construction of the museum: (i) the cataloging and the publishing of the artworks and the scenarios of visitation, and (ii) the building of a specific museum. In the teaching perspective, the teacher (i) uses the scenarios of visitation and (ii) can create learning challenges in order to motivate the students on testing their learning. And in the learning perspective, the students (i) navigate in the tool exploring the scenarios and (ii) answering the challenges. Adding the (b) brainstorming outcomes to the (a) comparative study allowed us to set up the main domain elements. Based on this, we developed a functional prototype to be run in both, web and Android platform, in order to validate the domain elements in the end-users' viewpoint. The activity was carried out in Brazilian's Elementary schools and museums with the participation of 174 students, 3 History teachers and one museum expert; the validation details are found in Welter et al. (2014). The results of the activity reinforced that the domain elements found in the previous sub-activity (a) could be inserted into the core assets of the SPL and into its variability list. During the collection of the audiences opinion, both - the teachers and the museum expert - outlined that to the development of the students' skills it would be important to provide a feature which allows the students to understand the historical event by making the relationship between past (from the museum artwork) and the facts of the present moment. This feature was added as variability in the SPL. For concluding the domain analysis step (i), the model of features (see Figure 1) - outlined the common features and the variabilities - was designed following the FODA (Feature-Oriented Domain Analysis) method (Kang et al., 1990).

![Figure 1. Model of features of e-MuseumSPL](image)

Based on the step (i) outcomes, the next DE step was the SPL architecture specification (ii) which must be figured out by meeting the attributes of being flexible and extensible, and according to the model of features. Since the architecture foundations of our approach were Web platform the architectural pattern MVC (Model View Controller) was adopted, mainly because this pattern naturally defines the responsibilities of each element of architecture. Allowing for the flexibility for dealing with the issues of end-user interface and interaction, the architecture specification was concentrated on the functional requirements. Additionally, the focus on functional requirements brings up a flexible interface to be run in different platforms. In the SPL conception, the architecture elements have to be adherence to the domain features. In this direction, the Domain-Driven Design approach (DDD) states principles that drive the SPL architecture have to be aligned to the business rules, simplify the reuse, reduce the coupling, and allow the use of independent technology product (Vernon, 2013). Following the DDD approach and the model of features (Figure 1), we proceeded with the identification of the objects on which the business rules were reflected: Museum, Scenery and Artwork - main similarities, and being the Challenge element classified as a variability.

Driving by the principle of independent layers (MVC pattern), the architecture of the individual domain object (DDD approach) was drawn and splitted into different layers (see Figure 2). The Model layer deals with the persistence requirements and is supported by the components: Entity, object of value (DTO), and Data Access Object (DAO) pattern. Aiming to provide the proper service to the Application layer, the Controller layer delivers from the Service component (Facade pattern) the functional system behavior to the control of the application (Application layer), that are represented by the product that is built from the SPL. In the same layer, the Constructor (Builder pattern) enables the creation of a complex domain object (objects that are composed by other objects) - in the museum domain are: artworks, scenarios and museum - which is used by the Service component. The proposed architecture reduces the complexity of the objects creation by invoking a single method. A Behavior element was added to the architecture - Dynamic layer - whose purpose is to
handle the components which implement behavior to the museum as guided navigation (core asset), or random (variability), or even the insertion of variabilities for sharing on social networks or other repositories. The non-dependence of technological tools and flexibility of the structure allows the developers to work with frameworks such as Spring, Java Server Faces among others in the Application layer for integration of their own components to the SPL architecture proposed in this work.

![Architecture of individual SPL components](image1)

Figure 2. Architecture of individual SPL components

Regarding the architectural foundation of the individual component and the model of feature, the e-MuseumSPL was designed by providing the core assets and the respective points of variability. The core assets of a SPL are composed not only by components, but also by documentations and other artifacts. In this sense, the core assets of the e-MuseumSPL also provide templates and documents, and automated unit tests that were developed for each of the mandatory components of the SPL (artwork, scenario and museum). The implementation of the e-MuseumSPL used the following web technologies: Java, Eclipse Link JPA (provides developers with a standards based in object-relational persistence), and Apache Maven1. Figure 3 illustrates the core assets in what are indicating the mandatory and the variable elements. The first version of e-MuseumSPL presents three types of components (in Figure 3 – the status of the elements were illustrated): (white) is a part of the core assets and was implemented; (gray) is a variability available; and (**) is a variability prepared to be implemented by extension. All the main components (classes) have extension points that can be identified by the stereotypes labeled as mandatory and variability. Taking into account the rules of object-oriented development that induces reuse (programming for super type and abstraction) and the behavior changing by extension, the Strategy design pattern was adopted in the model allowing for the adding of new behavior requirements as variability points.

![Core assets of e-MuseumSPL](image2)

Figure 3. Core assets of e-MuseumSPL

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1 Apache Maven allows describes how software is built, and its dependencies (https://maven.apache.org/).
Comparing our proposal with the works presented in Section 1 (Zhou et al., 2008; Cong et al., 2010; Falvo et al., 2014; Dalmon et al., 2012; Chimalakonda and Nori, 2012) on the perspective of reusing, the e-MuseumSPL promotes the intersection of elements inserted into the people's culture to the e-learning context. The development driven by domain oriented allows the specification of system elements closer to the elements of real world. In the perspective of using museums for e-learning, the works, Vavoula et al (2009) reported experiments with real museums, but not with a virtual platform. And Arends et al. (2009) discussed trends without concrete results.

2.1 First Experimentation: Application Engineering

The AE was driven by the fundamentals of SPL and of Empirical Software Engineering (Wohlin et al., 2012). Two groups of undergraduate students (6 participants divided into groups of three members) who belonged to the sixth semester of Computer Science course at University of São Carlos were invited to develop two different virtual museums by using the e-MuseumSPL. All participants signed a consent form for participation in the experiment. The profile of the participants - collected in a pre-interview - was: (a) They had consistent knowledge in the Web technologies that are a requirement to use the SPL; (b) only two participants - one in each group - have heard about the use of SPL and Apache Maven concepts - that is important to automatically generation of the museum instances from the SPL; and (c) only one of the members has had experience in software development in companies; the others had applied their developer's skills only for academic purposes. Given that the participants' profile was characterized by little experience on software development, a warming up - 4 hours splitted into two days - was carried out in order to leveling the participants knowledge about development of products by using a SPL: the architectural models (Figure 2 and 3) and all core assets (models, unit tests, etc) were presented to the participants. The participants implemented some examples using the e-MuseumSPL.

The minimum requirements requested for the participants were focused on the using of the web-based virtual museum by the students and not on the creation of the museum by the museum expert. The mandatory functional requirements were: the random and guided navigation and the offering of challenges for the students; the groups had freedom to include new requirements. As non-functional requirements were stated: the access should be via web and mobile devices (by responsive web interfaces); and the groups should use artworks of real museums. Considering the audiences and the museum theme, the groups had different targets: (i) Group 1 (G1) a museum for teaching Brazilian History (Museum of the Republic) to elementary school; and (ii) Group 2 (G2) a museum for education of Arts (Artworks Museum) to the high school.

As the participants of G1 and G2 had attended the HCI (Human Computer Interaction) course before the experimentation, they decided to build low fidelity prototypes to validate their ideas with potential end-users using POP tool (POP, 2016) based on low fidelity prototypes. Each group proceeded with prototypes evaluation with the participation of 3 end-users each one. After the evaluation, the groups developed the museum instances by using e-MuseumSPL and adopting SpringMVC, Bootstrap and AngularJS to implement the controller and application layers. The groups took different projects decisions: while G1 has developed a responsive web product that could be used in both PC and mobile platform; G2 followed the mobile first principles delivering a version produced by using web technologies. Figure 4 illustrates the museum instances (I – produced by G1 and II – produced by G2). Similarities and differences of each instance are highlighted: (A) the application's homepage; (B) the challenges - for G1 a scenario challenge: past-present relationship, for G2 a quiz; (C) guided navigation; and (D) extra requirement – in G1 the students can make annotations about a given scenario, and in G2 the image may be viewed in original size. The annotation feature was an important extension stating the Web 2.0 principle of collective construction of data; the students could exchange their ideas sharing the annotations in social network. After the implementation, the groups conducted tests with end-users whose results will be reported in next subsection 3.2. An important finding during AE is that it was not necessary to fix anything or add any modifications into the e-MuseumSPL to meet the requirements and to produce the instances. The developers validated all the elements of the core assets (tests, components, and documentation). Then we can conclude that the Goal 1 was achieved: the AE was successfully performed based on the DE outcomes.

To support the conclusions the Goal 2, we asked the groups before starting the product implementation, an estimation of time (number of hours and days) for the web-based virtual museum implementation (based on the mandatory requirement: functional and non-functional) considering they would not use a SPL. For the
delivering of the final product version, we set a deadline of one month. The groups reported similar time predictions for the implementation of both - functional and the interface/interaction requirements - a total: G1 - 24 days, and G2 - 26 days, with a dedication of around 6 hours/day. Taking into account their time prediction, the groups planned to use the remaining days for testing the museums with the end-users (G1 - 6 days; and G2 4 days). However, the real time spent was better than the prediction (around 32% less): G1 - 18 days and G2 - 17 days, maintaining the dedication of 6 hours/day. Within this achievement, the groups had time to conduct end-users tests - planning, conduction and analysis - and subsequently make some adjustments into the products according to users' feedback.

![Figure 4. Core assets of e-MuseumSPL](image)

In addition to the aspect of time spent during the museums development, we conducted a post-interview with the developers who had participated in AE, driving by two questions: (1a) state the positive and (1b) negative aspects of using the e-MuseumSPL; (2) if they agree they could build the same product, spending the same time without using the e-MuseumSPL. Regarding the question (1a), G1 highlighted as positive that they had "more time to focus on the front-end of the project, building an attractive interface; and the back-end coding and/or structure were totally supplied by the SPL"; G2 emphasized that "the controllers codification were easily built by the calling of SPL services"; and both groups pointed out as negative aspect (1b) "the initial time spent understanding how to use the SPL". For the question (2), G1 reported that "I think that we could not developed it spending the same time; we would have spent a long time in idealize the architecture - database, entities, and DAO – and in performing the tests, in writing the documentation..."; and G2 stated that "without the SPL, they had to track more carefully the requirements... the SPL forced them to follow an architecture, and then the requirements were fulfilled naturally...". Taking into account the answers, we can conclude that Goal 2 was successfully achieved. Even though the participants outlined the difficulties on the learning of how to use the SPL, they stated that the SPL brought advantages in saving time of the development. Concerning this, we can conclude that the groups could develop the products in a shorter time (less than 18 days) if they had previous experience the using of SPL concepts. The post-interview reinforced the conclusions of the Goal 1, thus the participants reported the widespread use of the core assets and the acceptance of the architecture.

**2.2 End-users Feedback**

As the groups (G1 and G2) had more time until the deadline, they decided to adopt the end-user testing based on the SUS (System Usability Scale) questionnaire, improving the products analysis over the usability point of view. Proposed by John Brooke in 1986, SUS states the product usability in five dimensions: ease of learning (D1), efficiency (D2), ease of memorization (D3), minimization of mistakes (D4), and user satisfaction (D5). Each dimension consists of one or more questions and the answers are requested in the Likert scale ranging from "strongly disagree" to "completely agree" (Bangor, Kortum and Miller, 2009). The set of ten questions must be presented in a prescribed sequence, because each one represents a specific SUS dimension. The user satisfaction index (ranging from 0 to 100) of SUS is calculated by the rules: for questions in the odd position, we subtract 1 to the user's response, and the questions in the even position the score is 5 minus the user's response. The minimum SUS factor is 70 for a product with a good usability. After getting the score of each question, add up the scores and multiply the result by 2.5. More information about SUS factor may be found in Bangor, Kortum and Miller (2009). Although SUS focuses on usability aspects, they can have a high impact on the software functional aspects. The usability problems can be caused not only by interface and interaction
aspects; functional requirements may interfere in the usability quality, especially in SPL that is driven by the architecture structure and the domain elements (Juristo, Moreno and Sanchez-Segura, 2007). Besides, Kang et al (1990) state that a feature is a user-visible aspect and a SPL focuses on features of the products, then the usability tests can reveal issues which impact in SPL functionalities.

The groups planned the tasks to be performed by the users during the usability testing, and recruited 10 end-users (5 of elementary school - G1 product, and 5 of high school - G2 product). All end-users – who had never had contact with the products - signed a consent term for participation in the tests. The tests – planning, conduction and analysis – were led in four days. At the end, the users should answer the SUS questionnaire individually. For the 5 users of the elementary school, G1 adapted the SUS questions in order to use a vocabulary closer to the participants’ age. Besides the SUS, the groups tracked the users’ actions performed during the tests by annotation observations of difficulties and doubt. The methodology used by the groups for the analysis was: review the notes gathered during the observation to identify problems of interaction and calculation of SUS factor.

In the tests carried out with G1 product, 3 of 5 users performed the tasks on tablets and the others on PC. On the other hand, in the G2 tests, 5 users executed the tasks exclusively on smartphones. The usability tests did not reveal serious shortcomings of interface and interaction, and none of functional error arose. Only two observations were written down by the groups which reported: G1 - some end-users have doubts about the challenge tasks during few seconds, but quickly overcome it; and G2 - the end-users tried to use some interaction patterns (pitch and spread movement to zoom, for example) that the product did not implement them in the first version.

After the tests, the developers groups calculated the SUS factor based on the students' answers. The media of SUS factor was considered satisfactory for both products, 87.5 and 83.5, for G1 and G2 respectively – being 70 the minimum SUS factor for a product with a good usability. Table 1 reports the SUS factor and the media per SUS dimension of each product by end-user. The numbers revealed to the developers the potential of the products in the end-users viewpoint (Goal 3). In addition, based on the SUS factor results and on the observations of the users’ interaction, we could infer that the e-MuseumSPL is a flexible product that can meet the needs of different audiences. Additionally, the end-users did not report misunderstandings about the elements used the museums instances, restating that the domain analysis could catch elements that represents the museums domain.

<table>
<thead>
<tr>
<th>Users</th>
<th>SUS Dimension</th>
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<tbody>
<tr>
<td></td>
<td>U1</td>
</tr>
<tr>
<td>G1</td>
<td>97.5</td>
</tr>
<tr>
<td>G2</td>
<td>77.5</td>
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</tbody>
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3. CONCLUSIONS AND FUTURE WORK

The contributions of this work can be highlighted in four aspects: (i) proposes the e-MuseumSPL to step the development of virtual museums up on the e-learning context providing the students of different levels of school with an open access tool; (ii) offers to the society the benefit of visiting museums on the web, reducing the geography distances; (iii) reports an empirical analysis that demonstrates the gain in productivity during the building of museums by allowing the developer to focus on the creation of different front-ends and on the performing of end-user tests; and (iv) states the evaluation on two viewpoints: developer and end-user. Tangentially, we could highlight an important contribution: demonstrates the feasibility of using reuse techniques for building e-learning tools by introducing good practices of software development into the process. Others exploratory works have to be conducted to obtain a deep study about the software development issues.

Besides the technical contributions, the development of virtual museums on the web also overcomes the problem of geographical distances, promoting social and educational gains. Addressing the proposal evaluation, two versions of museums - for teaching History and Arts - were built by two different groups of developers in order to meet two audiences: elementary school and high school. The evaluation results stated some reflections of the developers about the advantages and disadvantages of using the approach. In another
direction, we also reported the end-users’ feedback – students of elementary and high school - about their satisfaction on interacting with the museums. As future work we have planned to test other features of SPL, and developed a complete version of a virtual museum - features for museum experts, teacher, and students, through a partnership with a Brazilian Museum.

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