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A case study of development of a mobile application from an existing web information system

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Abstract

Purpose – This paper aims to present a case study of the Metamorphosis process in the development of a mobile application based on an existing web information system.

Design/methodology/approach – The paper presents the design and execution of a case study to investigate the feasibility of using the Metamorphosis process to create mobile applications based on existing web information systems. This case study reports the development of a mobile version from SIGEventos web information system.

Findings – The use of Metamorphosis process for the development of SIGEventos Mobile, based on SIGEventos web version, allowed the investigation of the feasibility of it on creation of mobile applications based on existing web information systems. This process was considered useful for creating mobile applications based on existing information systems.

Originality/value – This paper presents a case study of Metamorphosis process.

Keywords Mobile application, Case study, Metamorphosis process, Web information system

Paper type Case study

1. Introduction

In today's world, mobile computing is a reality in people's lives. For example, we use mobile devices to receive and answer our e-mails, like our friends' status, locate a place, order food and much more. Beyond that, we have strategies like Bring Your Own Device to access privileged company information and applications, which brings us even closer to the mobile computing context. Considering these devices' hardware, we have processing power with multiples cores, gigabytes of memory and dozens gigabytes of storage. In addition, we have sensors such as infra-red, Global Positioning System (GPS) and near field communication (NFC). Thus, information can be accessible from mobile devices that are powerful in terms of resources and lower sizes.

Moreover, there is a global trend toward the increasing number of users connected to the network via mobile devices. According to cnet, today we have more active mobile devices than people in the world: about 7.2 billion people and 7.3 billion mobile connections. This produces demands for information systems, mobile

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applications and content for such equipment. As a result of the diversity of features and capabilities offered by such devices, we observe an increase in their sales in 2014. Gartner (2014) says that smartphone sales grew 20 per cent in the third quarter of 2014, reaching 301 million units. Then, as a result of smartphones and tablets sales, there is also an increase demand for new applications. This can be seen by the growing number of application downloads on mobile application markets such as Google Play and Apple AppStore. About this fact, Gartner (2017) estimates that by 2017, mobile apps will be downloaded more than 268 billion times, generating a revenue of more than $77bn and making apps one of the most popular computing tools for users across the globe.

Thus, driven by this mobile computing scenario that is changing the way society accesses information, there is a growing demand for mobile applications. idc (2010) predicts that developers will create apps for virtually every aspect of a mobile user's personal and business lives that will "appify" just about every interaction between physical and digital worlds. There is a natural tendency for companies that have Web information systems to begin to adapt them to this computing scenario. It is an essential strategy for such systems to continue attracting and serving its users' needs. According to Giessmann (2012), 90 per cent of 250 information technology managers had plans to develop new mobile apps within their company by the end of 2011 and there is a considerable interest in mobile applications and willingness to invest in these technologies.

Therefore, we realize that many information systems are changing to this mobile computing context and provide ways to make their data available through mobile applications. However, according to Aquino Junior and Barroca Filho (2013), it is important to note that the development of these applications involves several activities, such as:

- catalog functionalities from the existing information system that should be present in the mobile application;
- engagement of stakeholders in the validation of the selected functionalities and assess the need for offline operations in each selected functionality;
- evolve the existing information system to enable integration with mobile applications;
- develop Web services on the existing information system to enable obtaining data by the mobile application;
- develop mobile application considering the target platform (Android, iOS, Windows Phone and Mobile Web);
- integrate with exclusive services on these devices, such as GPS, SMS and NFC; and
- publication and publicity of the mobile application.

As said before, this mobile version is not the redesign or copy of all functionalities from the based information system. It is important to review our knowledge of software development, particularly in processes, methods, techniques, patterns and architectural solutions for applications to this computing environment.

Finally, this article presents a process named Metamorphosis, which was designed to assist in the creation of mobile applications from existing Web information systems. This process provides a set of activities subdivided into four phases: requirements, design, development and deployment, which will be presented in Section 3. In Section 2, we outline related work. Section 3 presents the Metamorphosis process, focusing on phases, activities and work products. Section 4, in its turn, describes SIGEventos Mobile, a case study of the Metamorphosis process utilization[1], presented in the study by Barroca and Aquino Junior (2015). In Section 5, we present conclusions of this article and future works.

2. Related works

The creation of the Metamorphosis process started from the development experience of the first version of SIGAA Mobile[1] from SIGAA[2] Web information system. This development, described in Aquino Junior and Barroca Filho (2013), was conducted using two actions:

(1) Adaptation of existing features, created specifically for Web systems, to be also accessible from mobile devices. Such adaptation involves the development of applications in native platforms, like Android and iOS; the development of Restful Web Services; and the integration with existing enterprise software components which implement the business rules.

(2) Development of new specific features for mobile devices. These devices offer new possibilities and new technologies embedded in them; therefore, an important and promising initiative in this context would be the development of features not existent in the scope of old systems, which is only possible with mobile devices.

In this first experience, we categorized generic approaches related to: business, like choosing the most popular functionalities from the existing Web information system for the mobile version; technical, such as the reuse of business components from the existing Web information system; and UI (user interface), such as the creation of a logo and the usability review of the mobile version.

Thus, we noted that these approaches could be formalized into a process, and to provide a background for this process, we performed a systematic review to identify strategies, good practices and experiences reported in the literature about the development of mobile applications. With the result of this systematic review and our experience, we defined Metamorphosis, introduced in the study by Barroca and Aquino Junior (2014). Also in the study by Barroca and Aquino Junior (2014), we present its utilization for the development of SIGAA Mobile (second version).

The following section, Section 3, describes Metamorphosis process with more details, presenting its elements – phases and work products – and phases specifications – requirements, design, development and deployment.

3. Metamorphosis process

The Metamorphosis process consists in a set of activities organized in four phases (requirements, design, development and deployment) that should be considered for the creation of mobile applications from existing Web-based information systems.

3.1 Process elements

This section presents the elements of the Metamorphosis process, describing its phases and work products. The activities are described in Section 3.2.

Phases – The Metamorphosis phases, shown in Figure 1, includes:

- *Requirements*: Phase related to the selection of the information system's functionalities that should also be present in the mobile application. It has activities focused on the definition of the scope of the mobile application, along with elicitation and validation of requirements with stakeholders.
- *Design*: Phase related to the architectural design of the mobile application. It has activities focused on its design; and the creation of architectural solutions with technologies, frameworks, design patterns and best practices in development.
- *Development*: Phase related to source code implementation and software tests.
- *Deployment*: Phase related to application distribution. It has activities focused on publication and distribution of the mobile application.

3.1.1 Activities. The phases described in Section 3.1 are composed of 14 activities. These activities, covering from requirements to deployment phase, are defined as follows:

(1) *Identify functionalities*: The main goal of this activity is to identify functionalities on the existing Web information system that should be developed in the mobile application.

(2) *Validate functionalities*: This activity aims to promote the validation, by stakeholders, of the functionalities identified. At this moment, stakeholders may suggest new functionalities or discard identified functionalities.

(3) *Evaluate mobile context*: As described in Section 1, mobile computing has constraints that need to be observed during the development of mobile applications. Therefore, this activity evaluates if the functionalities validated by stakeholders are appropriate considering the limitations of this context.

(4) *Analyze adapting*: The purpose of this activity is to analyze possible adaptations of functionalities that are not appropriate considering the context of mobile computing, but that stakeholders evaluate as necessary for the mobile application. This analysis may result in changes on graphical user interface (GUI) and functionality work flow.

(5) *Select functionalities*: This activity consists of cataloging all the functionalities that were selected for the development with the documentation related to their functional requirements.

(6) *Evaluate offline*: Mobile computing has serious constraints regarding the network that may result on mobile device disconnection. Therefore, this activity

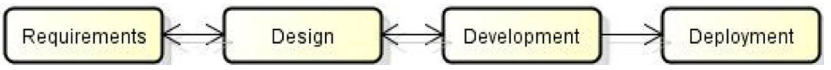

Figure 1.
Phases of the Metamorphosis process

aims to evaluate the need for selected functionalities to operate offline. Functionalities that need to have this offline operation feature should be highlighted because this need will influence the mobile application architectural design.

(7) *Choose platform*: The purpose of this activity is to define which platform will be used for the mobile application development. Nowadays, there are many different platforms such as Android and iOS and each one of them has their own characteristics. As described in Section 3, it is a common strategy to use hybrid technologies like PhoneGap for the development of these applications, thus avoiding the mobile devices fragmentation issue.

(8) *Design architecture*: This activity consists in designing the mobile application architecture and considering how it will be integrated with the existing Web information system.

(9) *Design services*: As the mobile application will connect with the existing Web information system to get data, this activity aims to design the Web services that enable this connection.

(10) *Implementation*: This activity is related to source code implementation considering the chosen platform.

(11) *Testing*: This activity consists in testing the mobile application.

(12) *Evaluate publishing need*: This activity aims to promote evaluation by stakeholders of the need to publish the mobile application in mobile apps market such as Google Play, Apple App Store and Windows Phone Store.

(13) *Publish application*: This activity consists in the actual publication of the mobile application on mobile apps markets such as Google Play, Apple App Store and Windows Phone Store.

(14) *Make publicity*: The main objective of this activity is to promote the mobile application release for potential users.

Figure 2 presents the activities considering their order of execution and how they are organized in each of the four phases of the Metamorphosis process.

3.1.2 Work products. The work products of the Metamorphosis process contain information that is produced throughout the execution of its activities. Thus, these products are:

- *Selected functionalities document*: It is a document generated by the activities of the requirements phase, presented in Table I. It contains descriptions of selected functionalities, links to access the documentation of these features and indications for adjustments and offline operation.
- *Deployment document*: It is a document generated by the activities of the deployment phase, presented in Table II. It contains a description of the mobile application, the mobile market and a link to download it.

3.2 Metamorphosis process specification

The four phases of the Metamorphosis process and its activities will be detailed in this section. These details consider the execution of activities (Barroca and Aquino

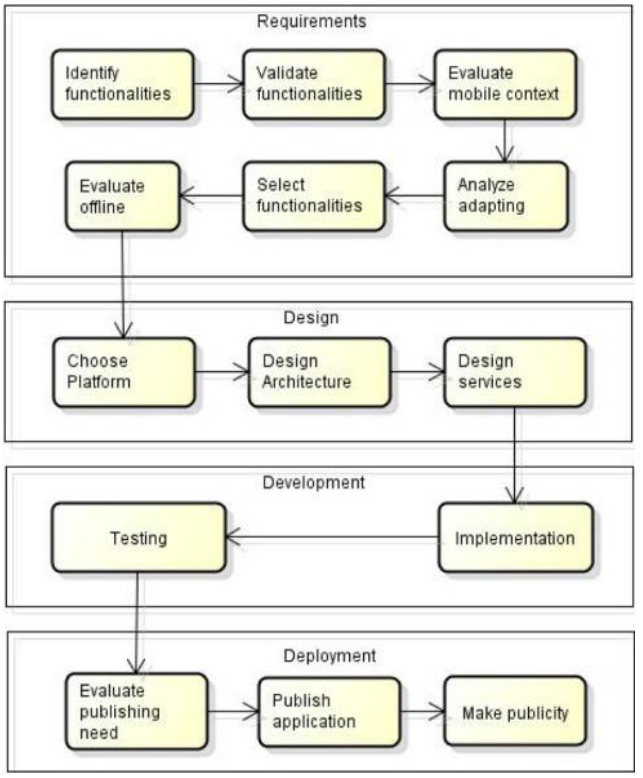

Figure 2. Metamorphosis process' activities in order of execution

Functionality	Link to documentation	Need to adapt	Need to operate
			Offline

Table I. Selected functionalities document's format

Description	Mobile market	Link to download

Table II. Deployment document's format

Junior (2014)) in each of its respective phases: requirements, design, development and deployment.

3.2.1 Requirements phase. At the beginning of the project, it is necessary to plan which functionalities are relevant in the context of mobile environments. The process of creating a mobile application from an existing Web enterprise system is not a direct mapping of functionality-to-functionality. This kind of simplification is a common mistake and must be treated carefully. Mobile devices have some intrinsic restrictions such as screen size, difficulties to type long texts and no guarantee of

network access availability. Moreover, it has a different mean of user interaction with touch support, gesture events and rapid actions. According to Barroca and Aquino Junior (2015), mobile applications tend to provide relevant advantages to their users in terms of design and usability. For this reason, it is important to know some strategies from the three layers design guideline proposed in the study by Nayebi (2012), which involves the creation of graphical user interfaces: offering shortcuts for functionalities, creating consistent graphical user interfaces for small devices and clearly distinguishing selected items.

Thus, the first activity of the requirements phase (Identify Functionalities), presented in Figure 3, is to analyze which features of the existing Web information system would be important in the mobile context. For this, four practices should be considered (Aquino Junior and Barroca Filho (2013)):

(1) choose popular functionalities;

(2) avoid long-steps functionalities or long-fill forms;

(3) adapt existing functionalities; and

(4) create specific functionalities for the mobile application.

The output of this activity is a list of preselected functionalities. This list will be validated with the stakeholders, which is the second activity of this phase (Validate Functionalities). If the preselected list is not validated by the stakeholders, there is a need to go back to the previous activity, which is the analysis of the existing system's functionalities. Otherwise, we can move on to the next activity, which is the evaluation of the preselected functionalities considering the mobile context

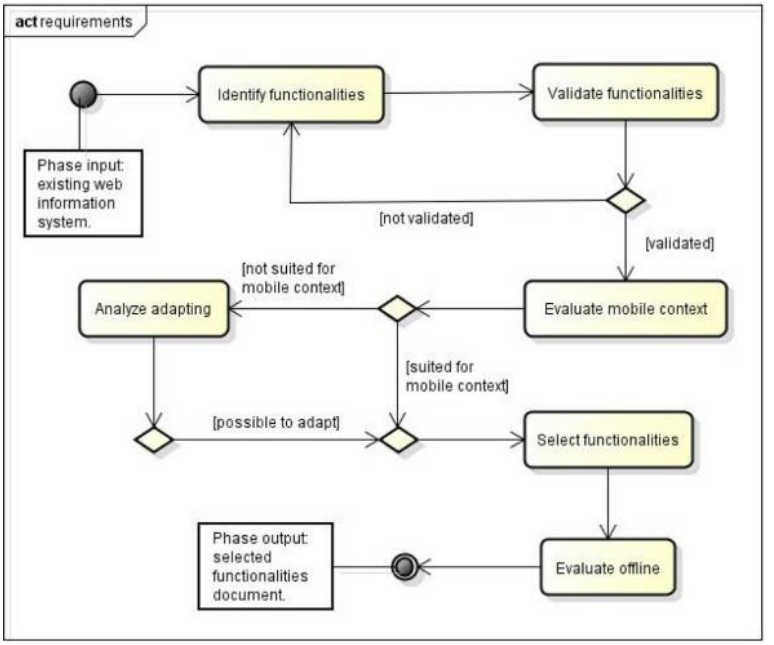

Figure 3.
Metamorphosis requirements phase

restrictions (Evaluate Mobile Context). In this activity, we verify the sizes of the forms and the amount of steps in these functionalities. If we consider a functionality suited for the mobile context, it moves on to the second output of this phase, which is a list of selected functionalities for development. Otherwise, if a preselected functionality is not suited for mobile context, we evaluated the possibility of adapting the functionality (Analyze Adapting), which can result, for example, in a new design for the operation, reducing the amount of fields and steps. If such a change is possible in the functionality, it is selected for development (Select Functionalities).

For each functionality selected for development, we evaluate the need to work offline (Evaluate Offline). This is important because mobile devices are often connected to a network using wireless connections, whose availability can be low. Moreover, the connectivity may be unstable while the user is interacting with the system. The necessity to run offline directly impacts on the next phase, which is the design. At the end of this phase, the Selected Functionalities Document, presented in Section 3.1, is created.

3.2.2 Design phase. The first activity of the design phase is the choice of the target platform (Choose Platform). Nowadays, there are many platforms available, such as Android, iOS, Windows Phone and Web Mobile. After choosing the target platform, the next challenge that needs to be addressed is how to integrate the mobile application with the existing system. Moreover, we need to be concerned about how to reuse its already implemented business components. The use of the layer pattern Ayob (2009) is particularly common in Web information systems. For this reason, a generic approach that can be used to integrate with the existing Web system is the definition of a new separated layer providing a set of services that must be used by the mobile application (Design Services). This new layer, which integrates with the existing business rules layer using the already implemented and stable code, is developed in the design phase, presented in Figure 4, where there is an activity to design this service layer. It is a strategy to use REST on the service layer. The use of a REST API simplifies the development of clients (mobile apps, Web and desktop versions) to consume information (Buschmann, 1996).

3.2.3 Development phase. After designing the mobile application's architecture and services, the development phase, which is presented in Figure 5, starts. The first activity of the development phase is the implementation of the mobile application functionalities' source code (Implementation). For this, the Selected Functionalities Document, described in Section 3.1, is forwarded to the developers, who use them to obtain details about the functionalities that will be implemented for the mobile application. As soon as the implementations are finalized, developers request their software tests (Testing). If the functionality developed is not validated (which means it does not pass all tests), the developers solve all bugs identified and request new tests. This phase only ends when all functionalities in the Selected Functionalities Document are implemented and there are no bugs detected in them.

3.2.3 Deployment phase. After the development of the mobile application, we enter the deployment phase, presented in Figure 6. The first activity of this phase is to evaluate the need for publishing the mobile application on mobile applications markets (Evaluate Publishing Need) such as Google Play and Apple App Store. According to Giessmann (2012), there are companies that operate their own mobile app stores to

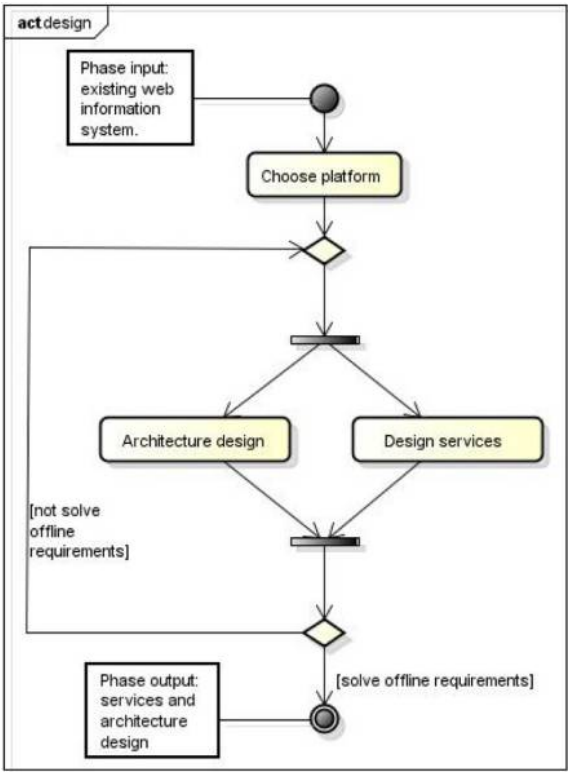

Figure 4.
Metamorphosis design phase

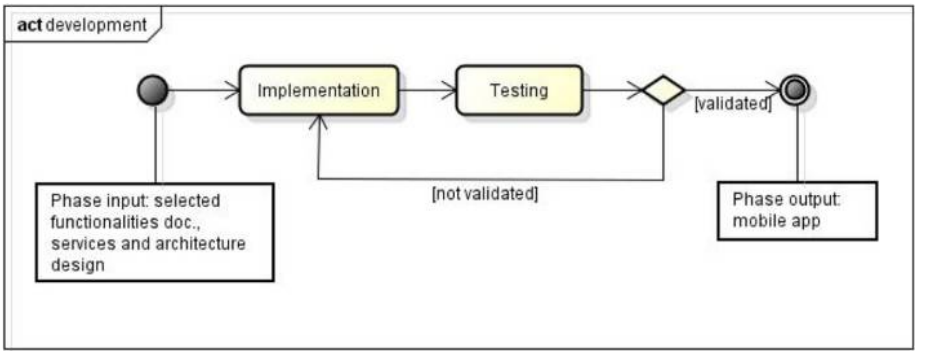

Figure 5.
Metamorphosis development phase

distribute the mobile applications to their employees, customers and partners. These app stores are known as "in-house" or "corporate" mobile app stores. It is important to discuss with stakeholders the need to publish the app in in-house or public mobile applications markets. If there is the need to publish the app in a public market (Publish Application), one of the most important activities of this phase is the publicity around the mobile application (Make Publicity). The potential user must know that this new

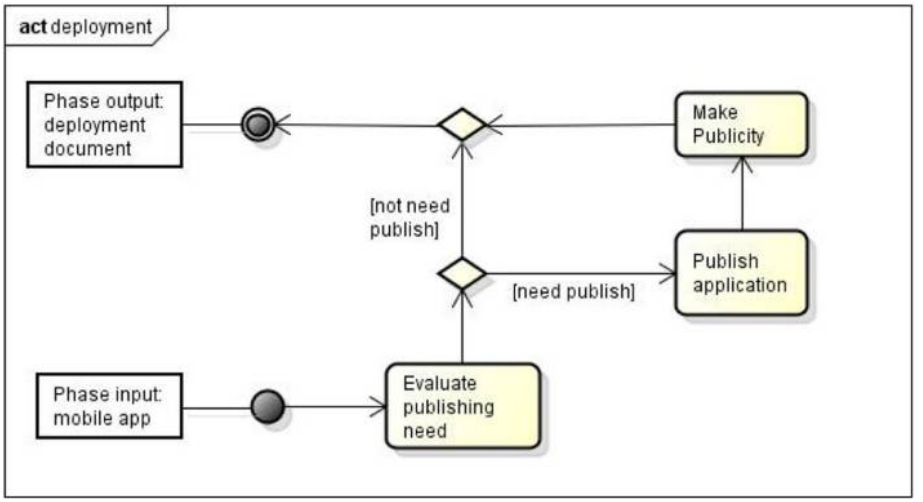

Figure 6.
Metamorphosis deployment phase

kind of enterprise system exists and they should be motivated to try this new way to access the system. Only publishing the application on a platform store, e.g. Android Play and Apple App Store, is not enough to make it be well known among users. For this reason, its existence should be well communicated to the target audience. At the end of this phase, the Deployment Document, presented in Section 3.1, is created.

4. SIGEventos mobile: a case study

This section describes the case study for the development of the mobile application SIGEventos Mobile. The main objective of this case study was to investigate the feasibility of using the Metamorphosis process to create mobile applications based on existing Web information systems. For planning and describing the results, we followed the guidelines proposed in the study by Zamula and Kolchin (2013), Yin (2003) and Kitchenham *et al.* (1995).

4.1 Planning

The case study planning includes a description of research questions, participating subjects, the object, analysis units, evaluated artifacts, evaluation criteria and procedures used for data collection.

Research questions: To reach the proposed objective, the case study should answer the following research questions:

RQ1. Is the Metamorphosis process useful for the development of mobile applications based on existing Web information systems?

RQ2. What are the benefits, problems and challenges resulting from the Metamorphosis process utilization?

To answer these questions, apart from observing and monitoring the development of SIGEventos Mobile, we applied two surveys[3] to the development team.

The first survey was about requirements phase and contained the following questions:

Q1. Do you consider that the requirements phase of the Metamorphosis process helped to select SIGEventos features that must be present in the mobile version?

Q2. Did you perform any activity during the requirements phase that is not addressed by this process?

Q3. Did you feel difficulty performing any activity during the requirements phase? – Regarding to complexity, do you consider that performed activities of requirements phase were easy, medium or hard?

Q4. Regarding to effort, do you consider performed activities of requirements phase were easy, medium or hard?

Q5. How much time did you spend performing each activity of requirements phase?

Q6. What are your suggestions for improving the requirements phase?

Q7. What do you consider as the benefits of using the requirements phase of the Metamorphosis process and why?

The second survey was about design phase and contained the following questions:

Q1. Do you consider that the activities of the design phase of the Metamorphosis process helped create an architecture that will facilitate the development of the functionalities selected for development?

Q2. Do you perform any activity during the design phase that is not addressed by this process?

Q3. Did you feel difficulty performing any activity during the design phase?

Q4. Do you consider that creating a layer of services for integration between Web systems and mobile application, proposed by the design phase, is the most appropriate solution to this context?

Q5. Regarding to complexity, do you consider that performed activities of design phase was easy, medium or hard?

Q6. Regarding to effort, do you consider that performed activities of design phase were easy, medium or hard?

Q7. How much time did you spend performing each activity of design phase? – What are your suggestions for improving the design phase?

Q8. What do you consider as the benefits of using the design phase of the Metamorphosis processand why?

Subjects – The Metamorphosis process was used by the mobile applications development team of the Informatics Management Office (SINFO) from the Federal University of Rio Grande do Norte (UFRN). This team consists of three programmers specialized in Android, iOS and PhoneGap. Therefore, our subjects were the three developers of this team.

Object – The object used for the case study was the Integrated system of conference management (SIGEventos)[4], presented in Figures 7 and 8. This Web system was designed to manage the conferences held at the Federal University of Rio Grande do Norte (UFRN). Thus, as access profiles on SIGEventos Web, we have:

Figure 7.
SIGEventos functionalities

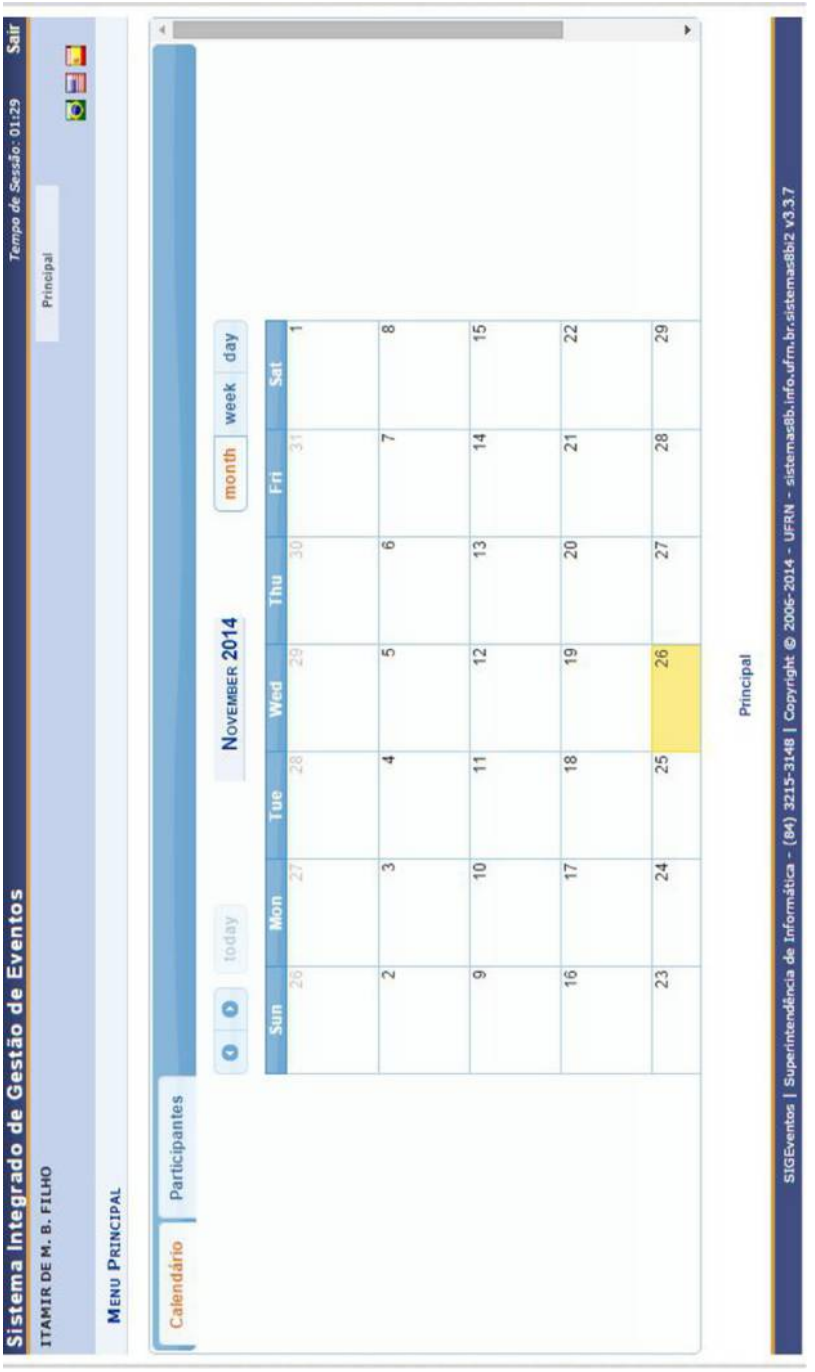

Figure 8.
SIGEventos event calendar

- *Evaluation Manager*: Performs the final evaluation of the paper, deciding whether it will participate or not in the conference.
- *Reviewer*: Performs evaluation of the paper submitted through an opinion, but is allowed to approve the role of this manuscripts in the conference.
- *Participant*: It is registered to use the system as a reviewer or to submit papers.

Summarizing the use flow of this system:

- a conference is created;
- for each conference, the reviewers must be registered;
- this conference has a registration period during which the work is submitted;
- after the submission of the papers, they are distributed to the reviewers;
- each reviewer performs his review. The evaluation manager determines, based on the reviewer's opinions, which papers will attend the conference and sends a notification to users who submitted papers; and
- at the end of the conference, the emission of certificates becomes available to those with approved papers.

SIGEventos was developed using open technologies such as Java, Hibernate, JavaServer Faces, Richfaces, Struts, EJB and Spring. It uses PostgreSQL as DBMS and is available via the JBoss application server. Finally, the SIGEventos Mobile was implemented using the Metamorphosis process.

Analysis units – The group of programmers and the users of SIGEventos were the analysis units of this case study. The programmers were analyzed during the execution of the Metamorphosis process and the users validated the preselected functionalities of requirements phase.

Data collected – In this case study, the following data were collected:

- the answers from the surveys presented in Section 4.1. And the answers of the survey to validate preselected functionalities of SIGEventos Mobile that is presented in Section 4.2; and
- the notes about the Metamorphosis process execution.

4.2 Metamorphosis process utilization

To start, we performed a meeting with the group of programmers to present the Metamorphosis process. At this meeting, all phases and activities of this process were detailed to them. In addition, we provided a document with the specifications of this process for future reference.

After this Metamorphosis process presentation meeting, the programmers began the requirements phase. In the first activity, known as Identify Functionalities, they performed a SQL query in SIGEventos logs trying to group and select the most commonly used functionalities. This technique, which uses the log database, is defined by the process to assist on this activity. The logs of query returned 76 rows with various links of all SIGEventos. This activity took around 1 h and 30 min. After this review of logs and a meeting with the team, developers reached functionalities which are identified in Table III.

With the list, developers began the second activity, which is Validate Functionalities, and created a survey to be answered by professors and students (stakeholders). This survey[5] listed the functionalities described in Table III allowing the stakeholders to evaluate them from 1 to 4, with 1 being the minimum score and 4 the highest score (in increasing order of significance). There were 20 responses. Also through this survey, it was possible to capture the stakeholders' suggestions for other functionalities.

The functionalities evaluated with maximum grade by more than 60 per cent of participants have been selected to be in the first version of SIGEventos Mobile. They are: Certificates of Paper Submissions, My Conferences Registrations, Conference Schedule and Conference Location. For a second version, the other functionalities and suggestions will be reviewed by the stakeholders. This activity took around five days, as it is depended on the application of the survey.

Continuing with requirements phase, after the validation of the functionalities by stakeholders, programmers moved on to the third activity, Evaluate Mobile.

Context in which the need to adapt each of these functionalities for the mobile environment was verified. The schedule and location functionalities were adapted for the use of GPS in mobile devices (Analyze Adaptation). The activities of analyzing and evaluating mobile context adaptation took about 1 h and 15 min to be performed.

The programmers selected these functionalities for development (Select Functionalities), and for each functionality, they evaluated the need for offline operation (Evaluate Offline). The schedule and registrations functionalities were evaluated as necessary to work offline. These activities, Select Functionalities and Evaluate Offline, took around 30 min to be performed. Finally, the programmers created the Selected Functionalities Document[6]. After the execution of this phase, the requirements phase survey, described in Section 4.1, was applied to programmers. The answers will be discussed in Section 4.3.

The programmers finalized the requirements phase and started the design phase. In the first activity of this phase, Choose Platform, Android was chosen for the development of SIGEventos Mobile. Then they started to Design Architecture and Design Services. In such activities, they spent about 8 h. This long period of time was because of the need for refactoring to separate the business components of SIGEventos Web and to create of SIGEventos REST. This SIGEventos REST has RESTFul services to enable the integration of SIGEventos Mobile with SIGEventos data. The motivation to separate was to make more independent projects at deployment and runtime level on

Table III.
Functionalities identified by the activity of identify functionalities of requirements phase

Functionality	Description
1. Certificates of paper submissions	List used to issue user's submissions certificates
2. My paper submissions	List of papers you have submitted. This list presents: paper title, status of submission, payment and submission period
3. My conferences registrations	List of your previous registrations. This list presents: the type of participation, registration status and conference period
4. Conference schedule	Calendar with general program of the conference
5. Conference location	Map with conference location and integration with Google Maps for navigation
6. Feedback of the talks	List with the conference talks where participants can perform evaluations (bad, good, very good and perfect)

JBoss application server and allow any application (desktop, mobile or Web) to use the services of SIGEventos REST. The components of SIGEventos and their interactions are shown in Figure 9. As in the requirements phase, at the end of the design phase, the survey described in Section 4.1 was applied. The answers will be discussed in Section 4.3.

After the architecture and services for SIGEventos Mobile were designed, the programmers started the development phase with the Implementation activity. All the functionalities presented on SIGEventos' Selected Functionalities Document were implemented. Each programmer spent around 12 h with it, and as the functionalities were implemented, tests were conducted. To perform the test, a tester from the Informatics Management Office Software Test Team used the mobile application for 3 h. The main SIGEventos Mobile screens are shown in Figure 10 and a video demonstrating the use of the key features is available on the following link: http://goo.gl/OM8SlP

Thus, the development phase was completed and the deployment phase began. At this phase, only the activity of Evaluate Publishing Need was held. It was decided to publish the SIGEventos Mobile on Google Play app market because of the number of potential users for this application, who can be professors, students, lecturers and participants, in other words, anyone from UFRN or not.

4.3 Answers to research questions

As described in Section 2, the subjects of this case study (three programmers) were observed during the execution of the Metamorphosis process for the creation of SIGEventos Mobile, and they answered all questions presented on surveys described in Section 4.1.

First, is the Metamorphosis process useful for the development of mobile applications based on existing Web information systems? To answer if the Metamorphosis is useful for creating mobile applications based on existing Web information systems, these surveys were organized considering the phases of requirements and design of this process. Regarding the requirements phase, all programmers considered that this phase assisted in the selection of SIGEventos' functionalities that should be present in its mobile version. Also concerning to this phase, programmers have not lacked any other activity that is not addressed by this process. This demonstrates that, in these programmers' perspective, the requirements phase of the Metamorphosis process is complete in terms of activities.

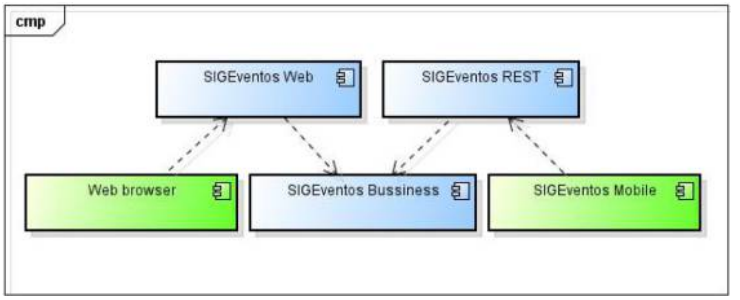

Figure 9.
SIGEventos components

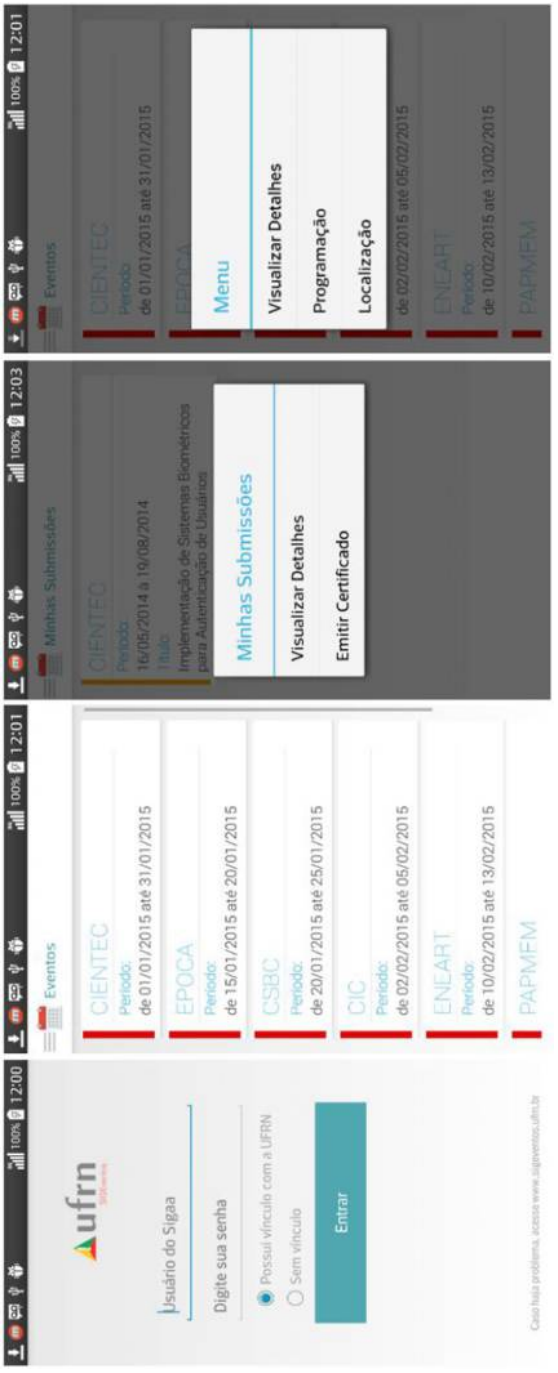

Figure 10.
SIGEventos Mobile main screens

At the design phase, all the programmers considered that this phase assisted to create an architecture that facilitated the development of functionalities for SIGEventos Mobile. Also regarding to activities not covered by the design phase, all developers stated that they did not perform any other activities not covered by the design phase of the Metamorphosis process.

Analyzing the answers, it can be considered that the Metamorphosis process is useful for creating mobile applications based on existing web information systems, as it helps in its creation and has complete and well-defined activities. It is important to emphasize that the development and deployment phases were not analyzed by these surveys. All these are available at: http://goo.gl/JfwTEU and http://goo.gl/uroh83

Second, what are the benefits, problems and challenges resulting from the Metamorphosis process utilization? To analyze the benefits, problems and challenges resulting from the use of the Metamorphosis process, the questions present in the surveys involved topics such as: difficulty in performing activity, complexity, effort and suggestions for it. Regarding the difficulty of carrying out any activity phase of the requirements, we noted that two programmers struggled to complete the execution of functionalities activity. This was because of communication problems with the stakeholders. This activity took around five days because it is depended on the responses of professors and students (stakeholders) to the validation survey about SIGEventos Mobile's functionalities, cited in Section 4.2. Thus, this activity was the longest in the requirements phase.

Regarding the difficulties of the design phase, developers had no difficulty in performing any of its activities. The programmers were also asked about the complexity and effort to perform the activities of the Metamorphosis process. With regard to the effort and complexity, two programmers considered that the execution of the requirements phase has medium complexity and effort. One of the programmers considered that the execution of this phase has easy complexity and effort. In the design phase, the answers about the complexity and effort were inconclusive, because each of the programmers answered with a different level of complexity and effort.

At the end of the surveys, the programmers were asked about suggestions for improvement of the requirements and design phases and benefits of the use of this process. At the requirements phase, programmers consider that its organization in step-by-step activities facilitates requirements elicitation. Moreover, according to one of the programmers, these well-defined activities led to an optimization of the development time, because it is known what must be done to raise the requirements of mobile application based on an existing Web information system. Also in this phase, according to one of the programmers, as such requirements elicitation based on an existing information system becomes simpler, it increases the chance to have a successful mobile application. Finally, according to the programmers, the benefit of the design phase is the conveniently organization of activities, as all activities improve the mobile application.

4.4 Threats to validity

For the case study, we evaluated four types of validity:

(1) *Construct validity*: The data capture of the implementation of this case study was carried out through the application of impersonal surveys (without identifying the programmer) to the programming team. Regarding the interpretation of

data, it was performed by two researchers which avoided errors and tendentious interpretations in the study.

(2) *Internal validity*: The case study realization was conducted with three programmers who have the same experience with the development of technologies for mobile devices (Android, iOS and PhoneGap). In addition, as in the first meeting, it held a presentation of the Metamorphosis process and provided a specification document, the trust was raised that the experience inherent factors, in developing applications for mobile devices and knowledge of the process of Metamorphosis programmers, were under control.

(3) *External validity*: This case study, performed to solve a real problem, enabled the creation of a mobile application based on a Web information system that will be used by thousands of users. Therefore, this allows to generalize the results of this case study and survey responses for industrial practice.

(4) *Conclusion validity*: In this case study, a control group did not exist because the goal was not to compare the Metamorphosis process with other software development process. So it was impossible to establish statistical relationships. The quantitative and qualitative data contributed to the assessment of the Metamorphosis process, regarding to its context, which is the development of mobile applications from existing Web information systems.

5. Conclusions and future works

The implementation of the Metamorphosis process for the development of SIGEventos Mobile, based on SIGEventos Web version, allowed the investigation of the feasibility use of this process for creating mobile applications based on existing Web information systems. We analyzed the requirements and design phases considering whether they are useful for creating applications for this context, along with its benefits and problems arising from its use. The surveys and observation of process execution were carried out in requirements and design phases and the results were presented in Section 4.3.

As limitations for this case study, we did not monitor development and deployment phases through surveys. In addition, we could not follow the active installations, as the execution of the case study was finalized at the first activity of the deployment phase.

Finally, the Metamorphosis process was considered useful for creating mobile applications based on existing information systems. Therefore, the main benefit of the Metamorphosis process is the well-defined step-by-step activities that bring to the goal of creating a mobile application based on an existing Web information system, a greater chance to be used and successful among its users.

Regarding to future work, we need to perform more cases studies of the use of the Metamorphosis process in creating mobile applications from information systems with different software technologies and architecture. Based on these collected evidence, this process may have its activities enhanced presenting details, for example, of how a particular functionality can be adapted to a mobile application considering the GUI and source code. This evidence collected may also serve for the development of components and architectural patterns to facilitate the integration between Web information systems and mobile applications.

Notes

1. Available at: https://play.google.com/store/apps/details?id=br.ufrn.sigaa.mobile
2. Available at: https://sigaa.ufrn.br/
3. Available at: http://goo.gl/forms/C8cK2qef55 and http://goo.gl/forms/2wqkqHS7PO
4. Available at: www.sigeventos.ufrn.br
5. Available at: http://goo.gl/forms/zQvNe9q7cG
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Further reading

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