International Journal of Web Information Systems

Development of mobile applications from existing Web-based enterprise systems

Itamir de Morais Barroca Filho Gibeon Soares Aquino Júnior

Received 11 November 2014
Revised 2 December 2014
Accepted 2 December 2014

Development of mobile applications from existing Web-based enterprise systems

Itamir de Morais Barroca Filho and Gibeon Soares Aquino Júnior
Federal University of Rio Grande do Norte, Natal, Brazil

Abstract

Purpose – This paper aims to identify and propose strategies for development of mobile applications from Web-based enterprise systems and introduce a process called Metamorphosis. This process provides a set of activities subdivided into four phases – requirements, design, development and deployment – to assist in the creation of mobile applications from existing Web information systems.

Design/methodology/approach – With the aim to provide a background to propose the Metamorphosis process, a systematic review was performed to identify strategies, good practices and experiences reported in the literature about creation of mobile applications.

Findings – This paper identifies and proposes strategies for development of mobile applications from Web-based enterprise systems and introduces a process called Metamorphosis. Then, this process is applied for creation of SIGAA Mobile.

Originality/value – The originality of this paper is the proposal of Metamorphosis process, that is, a process for development of mobile applications from Web-based enterprise systems.

Keywords Advanced web applications, Mobile computing for the internet, Migrating existing information

Paper type Research paper

1. Introduction

Mobile computing is becoming more present in daily life. Nowadays, smartphones and tablets have processing power that up until a little while ago only existed in "modern" computers, with large memory and processing capacity. According to Gartner (2013), 1.75 billion people have mobile phones with advanced capabilities and reality points to an even further growth in the use of such technology in the upcoming years. Thus, information became accessible from mobile devices that are considered powerful in terms of resources and lower sizes. There is a global trend towards increasing the number of users connected to the network via mobile devices, which in turn will produce an increasing demand for information systems, applications and content for such equipment.

Moreover, as a result of the diversity of features and capabilities powered by such devices, we can observe a large increase in their sales in recent years. Gartner (2014) estimates that 1.9 billion mobile phones will be shipped in 2014, a 5 per cent increase in comparison to 2013. 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. In this matter, IDC (2010) estimates that the number of mobile applications downloads will grow from 10.9 billion in 2010 to a total of 76.9 billion in 2014.

International Journal of Web Information Systems
Vol. 11 No. 2, 2015
pp. 162-182

1744-0084
DOI 10.1108/IJWIS-11-2014-0041

Thus, driven by this new computing scenario that is changing old habits and creating new ways to access information that up until now were only accessible via traditional computers, there is a growing demand for enterprise mobile applications (mobile enterprise application [MEA]). Ellison (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 fit this new computing scenario. This is an essential strategy for such systems to continue attracting and serving the needs of its users. According to Giessmann *et al.* (2012), 90 per cent of 250 IT managers had plans to develop new mobile apps within their company by the end of 2011, and there is a considerable interest in MEA and willingness to invest in mobile technologies.

The traditional information systems are experiencing a process of Metamorphosis to fit this computational context, and this new way to access information that is being made possible by current mobile devices. Regarding to this, it is important to emphasize that the creation of a mobile application from an existing Web information system is not the process of redesigning the graphical user interfaces (GUIs) to fit the screen size of the devices. We notice that famous applications such as Facebook and Twitter have different features, functionalities and forms of interactions in their Web and mobile versions. An example of a functionality that is different on these applications' mobile versions is the photo upload. In the mobile version, this functionality can activate the camera and also provide the upload directly from the device photo gallery. In the Web version, the user has to locate the photo using traditional file selection window. This form of interaction present in the mobile version, which uses the device's hardware, provides the users with more flexibility in their photograph publications and also provides a good experience in terms of usability. However, it is important to note that according to Aquino and Barroca Filho (2013), the development of these new types of applications involves several activities, such as: the construction of MEA considering development platform (like Android, iOS, Web Mobile); integration with the device's exclusive services such as Global Positioning System, short message service (SMS), near field communication (NFC) and other telephony services; development or evolution of existing Web and embedded systems; and integration between these systems and MEAs. We also cannot fail to consider constraints that this Metamorphosis should analyze, such as screen size and connectivity of mobile devices. It is important to review our knowledge of software development, particularly in processes, methods, techniques, patterns and architectural solutions for applications to fit this new computing environment.

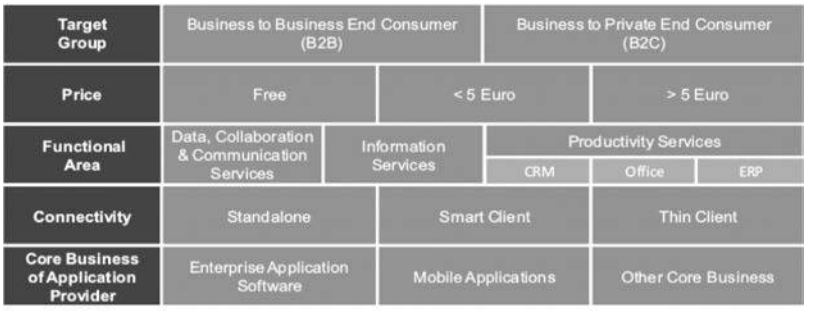
Finally, this article aims to identify and propose strategies for the development of mobile applications from Web-based enterprise systems and introduce a process called Metamorphosis [1], defined in Barroca Filho and Aquino (2014). This process that will be presented in Section 4 of this paper, provides a set of activities subdivided into four phases – requirements, design, development and deployment – to assist on the development of mobile applications from existing Web information systems. In Section 3, we present strategies for developing mobile applications identified through a systematic review that served as the background for creating the Metamorphosis process. In Section 2, we discuss the characteristics of MEAs and, in Section 5, we will present the Integrated System for Management of Academic Activities (SIGAA) Mobile,

a case study of the utilization of Metamorphosis process. Then, in Section 6, we present conclusions of this article and future works.

2. Mobile enterprise applications

The MEAs are mobile applications developed with the purpose of providing enterprise information obtained from Web information systems. In a study by Giessmann *et al.* (2012), an interview with six experts where everyone agreed with the definition of MEA was made and they added that, considering the enterprise context, the company aggregates value by increasing productivity and/or reducing cost. Also, in a study by Giessmann *et al.* (2012), the experts believe that the potential of the MEA is in customer support: sales and service applications. This may be seen at mobile applications markets (Google Play and Apple App Store) where there is a considerable range of customer support applications such as: applications for airline check-in services, enterprise applications to consult deliveries and applications for sales. This kind of MEA is defined by Giessmann *et al.* (2012) as business to private end consumer (B2C), whose goal is the client integration with the company's business information. Kolici *et al.* (2013) present some scenarios of using mobile applications in businesses and enterprises such as intelligent advertising, customers profiling and loyalty and collective intelligence. The classification scheme for mobile enterprise applications defined by Giessmann *et al.* (2012) is presented in Figure 1.

In this new computing scenario, mobile devices represent a faster access to information, which can be decisive, given the competitiveness of the business sector. Moreover, this new kind of interaction brings convenience to users of Web information systems. As the MEAs are created from existing information systems, it is important to know that during the development which activities must be performed to ensure that they fit the constraints of the mobile computing scenario. Among these constraints, there is: small screen size, connectivity, display resolution and data entry methods (Nosseir *et al.*, 2010) that make it complicated to type long texts. It is also essential that the MEAs offer the users a good experience. To assist with these issues, we performed a systematic review presented in Section 3, with the aim of identifying strategies for development of mobile applications. Then, we used these strategies as a background to create the Metamorphosis process.



Source: Giessmann *et al.* (2012)

Figure 1.
Classification scheme for mobile enterprise applications

3. Strategies for development of mobile applications

With the aim to provide a background to propose the Metamorphosis process, a systematic review was performed to identify strategies, good practices and experiences reported in the literature about creation of mobile applications. Sections 3.1, 3.2, 3.3 and 3.4 will present the review process considering planning and conduction of this systematic review. Planning and conduction of the systematic review were guided by the guidelines defined by Kitchenham and Charters (2007).

3.1 Research questions

Considering the context of the proposed study, this systematic review should answer the following research questions:

RQ1. What are the existing strategies and good practices for creating mobile applications?

RQ2. What are the reported experiences in creating mobile applications from existing information systems?

3.2 Inclusion and exclusion criteria

This systematic review included studies published between 2007 and September 2014. It intended to pursue research on the second generation of mobile applications platforms (Giessmann *et al.*, 2012) introduced with the release of the first iPhone. Studies – which were all written in English – were included in the review if they had processes, techniques, strategies and good practices for the creation of mobile applications.

Furthermore, duplications returned in more than one research base were ignored. The returned systematic reviews were not excluded because their references were observed.

3.3 Electronic sources

The studies' selection was conducted in the main data repositories in academic computing area. These repositories are listed in Table I.

3.4 Search string

To formalize the search string, we used terms related to our main objective, which is obtaining studies about strategies, good practices and experiences in creating mobile applications. Thus, the following search string was defined:

- "Mobile application" and "Web" and ("process" or "methods" or "techniques" or "strategies" or "practices" or "development").

After performing searches with this string on the repositories listed in Table I, the quantity of published papers defined in Table II was found.

Name	Address
IEEExplorer	http://ieeexplore.ieee.org
ACM digital library	http://dl.acm.org
Springer link	http://link.springer.com

Table I.
Electronic sources

3.5 Study selection

Phase 1 was the analysis of titles and abstracts of all 973 papers on these three data sources. After this analysis, studies not related to the topic of this review were discarded. With the completion of Phase 1, the quantity that remained in the systematic review is described in Table III. All nine papers that remained after Phase 1 were: Ayob *et al.* (2009), Hernandez *et al.* (2013), Harrison *et al.* (2013), Kolokolov *et al.* (2013), Hsieh *et al.* (2012), Zamula *et al.* (2013), Picco *et al.* (2014), Thebault *et al.* (2013) and Grønli *et al.* (2014).

3.6 Systematic review conclusions

Through the perusal of these nine papers, we infer some conclusions trying to answer the questions proposed by this systematic review. Regarding the existing strategies and good practices for creation of mobile applications, there is a strong concern about usability issues during the construction of GUIs. A good GUI can definitively attract the user to use the application over and over again and avoid the frustration of not wanting to use it again (Ayob *et al.*, 2009). GUIs should be friendly and intuitive for the user (Hernandez *et al.*, 2013). Therefore, user involvement and especially usability evaluations considering user requirements become truly important.

In a study by Ayob *et al.* (2009), they propose a three-layer design guideline for mobile applications. This guide, presented in Figure 2, has three phases: analysis (context of use), design (medium context) and testing (evaluation context). Each of these steps presents activities that assist in the creation of GUIs for mobile applications, such as: identifying and documenting the car user tasks, providing informative feedback, designing graphical interfaces for small devices, usability testing and field studies. According to Harrison *et al.* (2013), there are several methodologies for evaluating usability in a mobile application: controlled experiment, field study, survey, case study, informal assessment, archival research and specialists' evaluation.

Still regarding good practices and strategies, we observed in the analyzed studies a trend to create hybrid mobile applications using Web technologies and principles, such as HTML5, Cascading Style Sheets (CSS) and Web services RESTFul. A hybrid application is developed using these Web technologies and then is packaged in a container, becoming a native app that access the application programming interfaces (APIs) of mobile devices platform (Kolokolov *et al.*, 2013). The main reason for creating hybrid applications is that there are several mobile platforms, and it is often not feasible to develop native applications for each platform. This is known as device fragmentation (Hernandez *et al.*, 2013). PhoneGap, Titanium Mobile, Rhodes and MoSync Software Development Kit (SDK) are frameworks for creating hybrid applications.

Mobile applications consume and produce information and, therefore, need access to databases related to its data. For this, we observed in the papers the use of

Table II.
Quantity of papers found after perform search with the string

Springer link	ACM digital library	IEEExplorer
800	63	110

Table III.
Quantity of papers that remained after Phase 1

Springer link	ACM digital library	IEEExplorer
1	3	5

Phase	Existing Guideline	Activities
Analysis (Context of Use)	Specify user and organizational requirement	1. Identify and document user's tasks 2. Identify and document organizational environment 3. Define the use of the system
Design (Context of Medium)	Produce design solution	1. Enable frequent users to use shortcuts 2. Offer informative feedback 3. Consistency 4. Reversal of actions 5. Error prevention and simple error handling 6. Reduce short-term memory load 7. Design for multiple and dynamic contexts 8. Design for small devices 9. Design for speed and recovery 10. Design for "top-down" interaction 11. Allow for personalization 12. Don't repeat the navigation on every page 13. Clearly distinguish Selected items
Testing (Context of Evaluation)	Evaluate design against user requirements	1. Quick and dirty approach 2. Usability testing 3. Field studies 4. Predictive evaluation

Source: Ayob *et al*. (2009)

Figure 2.
Three layers design guideline

Web services RESTFul. Standard protocols simple object access protocol (SOAP) and representational state transfer (REST) complete support HTTP connections with simple data formats such as XML and JSON (Hsieh *et al.*, 2012). Furthermore, the use of a REST API simplifies the development of clients (mobile apps, Web and desktop versions) that consume information (Zamula *et al.*, 2013). Also, related to strategies, according to Picco *et al.* (2014), the design phase of mobile applications requires architectural patterns that capture common approaches and good practices to consider concerns as disconnected operation (offline) transactions. Also in this work, it is stated that the deployment of mobile applications will be usually accomplished in the future on the applications market because they make them widely and quickly available to users. In summary, a review of good practices and strategies identified by this systematic review for development of mobile applications is presented as follows:

- creation of graphical interfaces for mobile applications using the three layers design guideline (Ayob *et al.*, 2009);
- performing usability evaluations on mobile applications using techniques of controlled experiment, field study and questionnaires (Harrison *et al.*, 2013);
- development of hybrid mobile applications using technologies like HTML5, CSS and Javascript. The main advantage of developing hybrid applications is to ensure portability and minimize the effect of fragmentation devices (Kolokolov *et al.*, 2013; Hernandez *et al.*, 2013);
- use of SOAP and REST protocols for providing information from the information system to mobile application (Hsieh *et al.*, 2012; Zamula *et al.*, 2013);
- evaluating the need for disconnected operation features of mobile application (Picco *et al.*, 2014); and
- use of applications markets to distribute mobile applications (Picco *et al.*, 2014).

Among the papers read, only Thebault *et al.* (2013), Grønli *et al.* (2014) and Zamula *et al.* (2013) reported the creation of mobile apps. These reports are mainly related to their functional requirements and present the use of some best practices as mentioned above.

4. Metamorphosis process

After the literature review described in Section 3, we noted that there are no strategies defined specifically for the creation of mobile applications based on existing Web information systems. Nevertheless, many of the strategies identified by this review can be used for development of enterprise mobile applications. Therefore, we propose in this section the Metamorphosis process. This 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 enterprise applications from existing Web-based information systems.

4.1 Process elements

This section presents the elements of the Metamorphosis process, describing phases, activities and work products. The activities are described in this section with few details because they will be completely specified in Section 4.2.

4.1.1 Phases. The Metamorphosis phases, shown in Figure 3, are:

- *Requirements*: Phase related to selection of the information system's functionalities that should also be present at the mobile enterprise application. It has activities focused on definition of the scope of MEA, elicitation and validation of requirements with stakeholders.
- *Design*: Phase related to the architectural design of the mobile enterprise application. It has activities focused on its design, 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 MEA.

4.1.2 Activities. The phases described in Section 4.1.1 are composed by 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 on the mobile enterprise 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

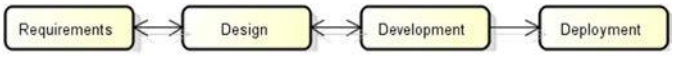


Figure 3.
Phases of the Metamorphosis process

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 enterprise application. This analysis may result in changes on GUI and functionality workflow.

(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 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 enterprise application architectural design.

(7) *Choose platform*: The purpose of this activity is to define which platform will be used for the mobile enterprise 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 enterprise application architecture and considering how it will be integrated with the existing Web information system.

(9) *Design services*: As the mobile enterprise application will connect with the existing Web information system to get data, this activity aims to design the Web services that enable this connection. As described in Section 3, it is strategic to use REST for creation of Web services.

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

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

(12) *Evaluate publishing need*: This activity aims to promote evaluation by stakeholders of the need to publish the mobile enterprise 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 enterprise 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 enterprise application release for potential users.

Figure 4 presents the activities considering their order of execution and how they are organized in each of the four phases of the Metamorphosis process.

4.1.3 Work products. The work products of the Metamorphosis process contains information that is produced by the execution of its activities. Thus, these products are:

- *Selected functionalities document*: It is a document generated by the activities of the "Requirements" phase with format presented in Table IV. 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 "Implementation" phase, with format presented in Table V. It contains a description of the mobile enterprise application, the mobile market and a link to download it.

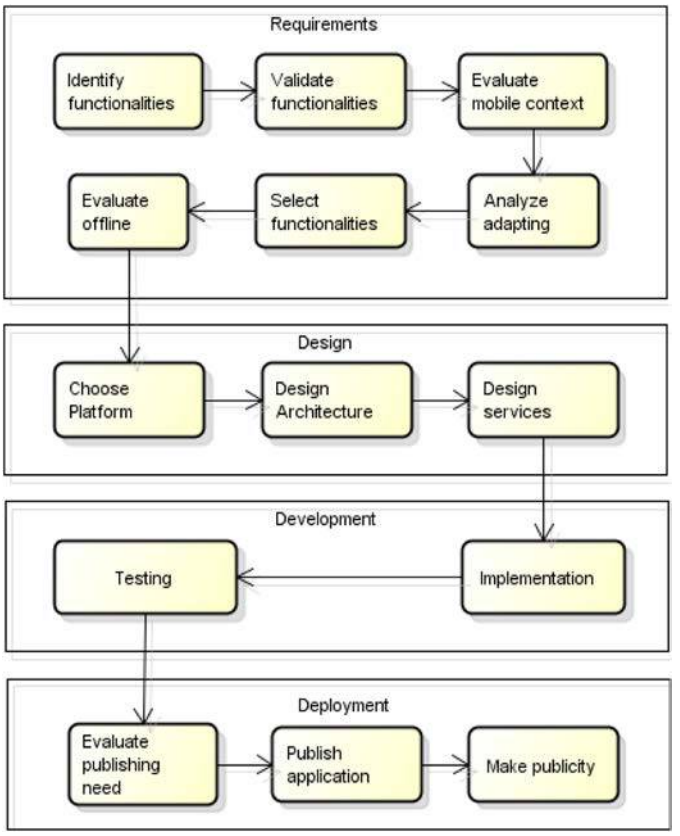


Figure 4.
Metamorphosis process' activities in order of execution

Table IV.
Selected functionalities document's format

Functionality	Link to documentation	Need to adapt	Need to operate offline

4.2 Metamorphosis process specification

The four phases of the Metamorphosis process and its activities will be detailed in Sections 4.2.1, 4.2.2, 4.2.3 and 4.2.4. These details consider the execution of activities in each of its respective phases: requirements, design, development and deployment.

4.2.1 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 Nayebi *et al.* (2012), 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 by Ayob *et al.* (2009) and presented in Section 3, which involves creation of GUIs: offering shortcuts for functionalities, creating consistent GUIs for small devices and clearly distinguishing selected items.

Thus, the first activity of the requirements phase (identify functionalities), presented in Figure 5, 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:

Description	Mobile market	Link to download

Table V.
Deployment document's format

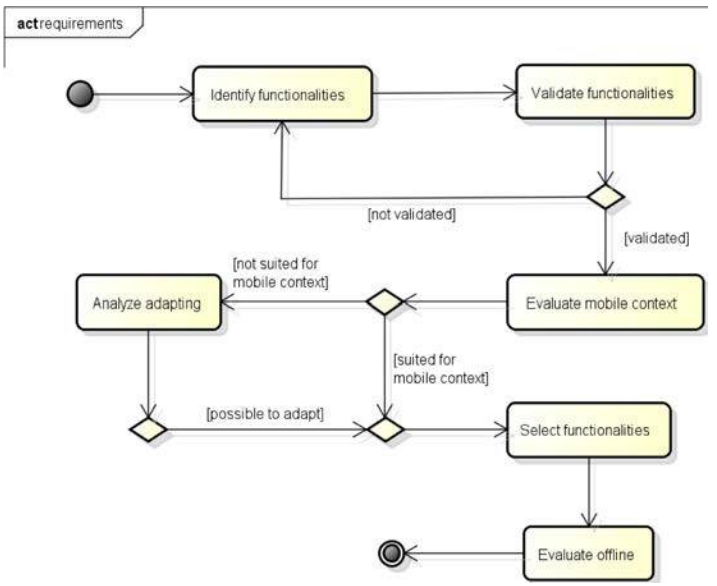


Figure 5.
Metamorphosis requirements phase

(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 pre-selected 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 functionalities pre-selected considering the mobile context restrictions (evaluate mobile context). In this activity, we verify the sizes of the forms and the amount of steps on 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 pre-selected 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, the design. At the end of this phase, the selected functionalities document, presented in Section 4.1.3, is created.

4.2.2 Design phase. The first activity of the design phase is the choice of the target platform (choose platform). As seen in Section 1, 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 MEA with the existing system. Moreover, we need to be concerned about how to reuse its already implemented business components. Nowadays, the use of the layer pattern (Buschmann *et al.*, 1996) 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 integrates with the existing business rules layer using the already implemented and stable code, and it is developed in the design phase, presented on Figure 6, where there is an activity to design this service layer. It is a strategy to use REST on the service layer. As we saw in Section 3, the use of a REST API simplifies the development of clients (mobile apps, Web and desktop versions) to consume information (Zamula *et al.*, 2013).

Although the integration with the business layer seems so simple, it may require some refactoring in the existing code. This need is caused by a habitual phenomenon called "software architecture erosion", where the violation of architecture principles during the system maintenance occurs without a malicious intent (De Silva and Balasubramaniam, 2012). Usually, the business layer on the existing Web system is

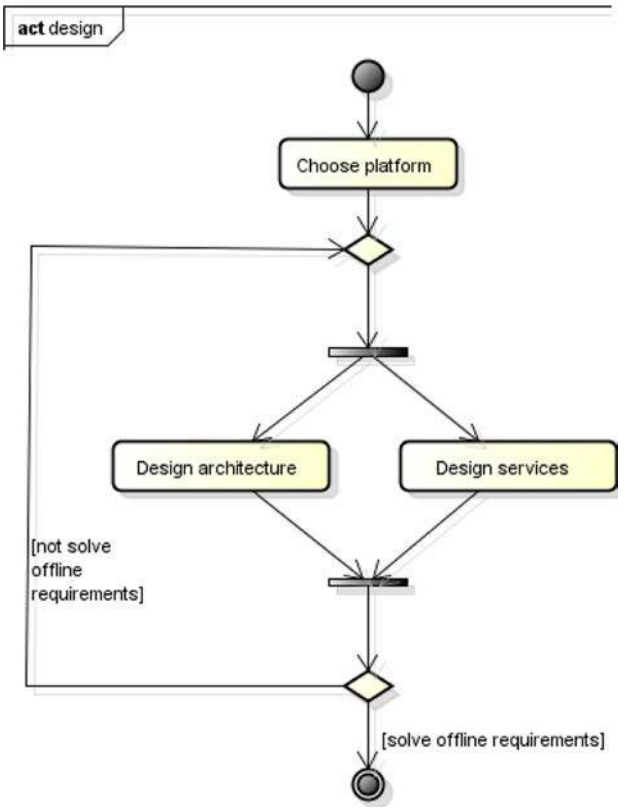


Figure 6.
Metamorphosis design phase

prepared to provide services independently of its client technology, but it is used and matured integrated only with a unique type of client, the Web view layer. For this reason, it is important to plan some rework to reform the business layer and prepare it to the expected integration. The other activity of this phase is the architecture design of the mobile application using known techniques of definition (Bass *et al.*, 2013), documentation and evaluation (design architecture). In this activity, we develop an architecture containing what is needed for an MEA to run related to source code, such as: design patterns, frameworks and technologies. Once we develop the service layer on the existing Web system and MEA architecture, which are artifacts of design phase, we need to verify if our solutions solve the necessity of running offline detected on requirements phase. If it does, we are ready for the development of MEA selected functionalities, otherwise we need to alter these artifacts. After this phase, the development actually starts.

4.2.3 Development phase. After designing the architecture and the services of the MEA, the development phase starts, presented in Figure 7. The first activity of the development phase is the implementation of the MEA functionalities' source code (implementation). For this, the selected functionalities document, described in Section 4, is forwarded to the developers, who use them to obtain details about the functionalities

that will be implemented for the MEA. 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 on the selected functionalities document are implemented and there are not any bugs detected on them.

4.2.4 Deployment phase. After the development of MEA, we enter the deployment phase, presented on Figure 8. The first activity of this phase is to evaluate the need for publishing the MEA on mobile applications markets (evaluate publishing need) such as Google Play and Apple App Store. According to Giessmann *et al.* (2012), there are companies that operate their own mobile app stores to distribute MEA to their employees, customers and partners. These app stores are called "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 MEA (make publicity). The potential user must know that this new 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, 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 4.1.3, is created.

5. SIGAA mobile: a case study of the Metamorphosis process utilization

This section is organized into three Subsections: 5.1, 5.2 and 5.3. In Subsection 5.1, we present SIGAA, which is an enterprise Web system developed to provide

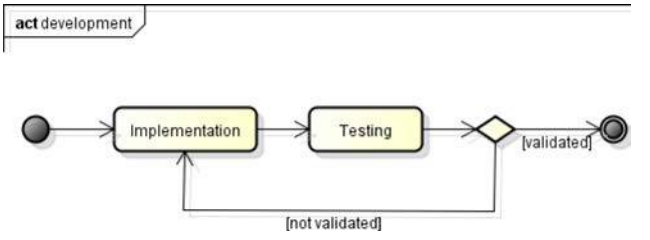


Figure 7.
Metamorphosis development phase

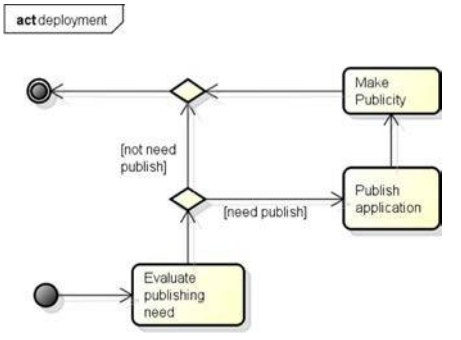


Figure 8.
Metamorphosis deployment phase

students and professors with academic information from the Federal University of Rio Grande do Norte (Universidade Federaldo Rio Grande do Norte [UFRN]). In Subsection 5.2, we present the Metamorphosis process application on SIGAA for SIGAA Mobile's development. And finally, in Subsection 5.3, we present SIGAA Mobile, which is a MEA to provide SIGAA users a new way to access academic information contained in it.

5.1 SIGAA

SIGAA is a corporative Web system developed by UFRN that computerizes the business process of the academic area through the modules that composes it: graduation; master's degree (*strictu* and *latu sensu*); technical study; elementary and high school; research projects' submission and control; research grants; academic extension's actions control; teaching projects' submission and control (monitoring and innovation); registration and reports of professors' academic production; and a virtual teaching place called "virtual class". These modules are presented in Figure 9 and are enabled according to user profiles.

Nowadays, SIGAA has 41,397 users divided into the following profiles: students, professors and technicians. This Web system was developed using open technologies such as Java, Hibernate, JavaServer Faces, Richfaces, Struts, Enterprise JavaBeans (EJB) and Spring. It uses PostgreSQL as database management systems (DBMS) and is deployed into JBoss Application Server.

In terms of physical metrics, SIGAA has 6,46,382 lines of code, 4,750 classes and 1,135 tables divided into 40 schemes. In terms of functional metrics, it contains 1,858 functionalities, accounting a total of 22,369 function points based on the Netherlands Software Metrics Association (NESMA) account method. It depends on a software architecture also developed by UFRN, serving as an infrastructure to this corporative system. The relationships between these projects are defined into three layers: data access, presentation and business:

Figure 9.
SIGAA functional modules

(1) The data access layer is responsible for persistence and data queries into database and contains Data Access Object, Hibernate and Java DataBase Connectivity.

(2) The presentation layer is responsible for controlling interaction between users and system and contains JavaServer Pages (JSPs), Web services and JavaServer Faces (JSF).

(3) The business layer is responsible for centralizing the domain business system logic. This layer contains EJB Commands.

With the SIGAA's success in managing UFRN's academic activities, this system has been released for others Brazilian federal universities since 2009. Nineteen universities are currently using SIGAA.

5.2 Metamorphosis process utilization on SIGAA

For the development of SIGAA Mobile, we used the Metamorphosis process detailed in Section 4 on SIGAA Web. The utilization of the activities of this project is presented in this section.

Starting from the requirements phase, an analysis of the functionalities in SIGAA Web was made. As we saw in Section 5.1, regarding the amount of functionalities, SIGAA is an extensive information system, and it makes no sense to develop each of these features for the mobile context. Thus, as described in Section 4.1, we minimized the scope for the mobile version, selecting only the most popular and most suitable features for this context. After such analysis, we tried to involve several professors and students (stakeholders) to raise their validations, expectations and feedbacks about pre-selected functionalities for the SIGAA Mobile. After the validation by the stakeholders of the functionalities that were preselected for development, we had a set of functionalities that concerned mostly in SIGAA's virtual class. The pre-selected functionalities were then evaluated considering the constraints of the mobile context described in Section 1. Some of them did not fit this context due to the amount of fields and steps. The others, which were the ones that fit the context, were selected for development. Those that did not fit were analyzed to be adapted. All were able to be adapted and were selected for development. After having selected the functionalities for development, we evaluated the need for offline operation. Some operations such as register frequency of students were evaluated as necessary to work offline. At the end of the requirements phase, we had a list of operations selected for development and a list of which ones needed to work offline. The SIGAA Mobile selected functionalities document is presented in Table VI.

Then, we moved on to the design phase, where SIGAA Mobile architecture and SIGAA Web services layer were developed. After these developments, we analyzed if the SIGAA Mobile architecture attended offline requirements. The services layer developed composed by RESTFUL Web services who use the components of SIGAA business layer (session beans, and utility classes persistent entities) is presented in Figure 10.

As warned in Section 4.2, it was necessary to perform refactoring to enable this integration through service layer, because specific objects from Web frameworks were found beyond the business layer boundary. SIGAA business layer was designed for interaction with the presentation layer only through Web browsers, and the introduction of this new type of client (mobile devices) demanded that we removed these

Functionality	Link to documentation	Need to adapt	Need to operate offline
My class	www.info.ufrn.br/wikisistemas/doku.php?id=desenvolvimento:especificacoes:sigaa:portal_do_discente:casos_de_uso:turmas_do_semestre	No	Yes
Class > grades	www.info.ufrn.br/wikisistemas/doku.php?id=desenvolvimento:especificacoes:sigaa:portal_do_discente:turma_virtual:casos_de_uso:menu_turma_virtual:turma:principal	No	Yes
Class > frequency	www.info.ufrn.br/wikisistemas/doku.php?id=desenvolvimento:especificacoes:sigaa:portal_do_discente:turma_virtual:casos_de_uso:menu_turma_virtual:turma:principal	No	Yes
Class > news	www.info.ufrn.br/wikisistemas/doku.php?id=desenvolvimento:especificacoes:sigaa:portal_do_discente:turma_virtual:casos_de_uso:menu_turma_virtual:turma:principal	No	Yes
Class > students	www.info.ufrn.br/wikisistemas/doku.php?id=desenvolvimento:especificacoes:sigaa:portal_do_discente:turma_virtual:casos_de_uso:menu_turma_virtual:turma:principal	No	Yes
Class > lecture topics	www.info.ufrn.br/wikisistemas/doku.php?id=desenvolvimento:especificacoes:sigaa:portal_do_discente:turma_virtual:casos_de_uso:menu_turma_virtual:turma:principal	No	Yes
Documents	www.info.ufrn.br/wikisistemas/doku.php?id=desenvolvimento:especificacoes:sigaa:portal_do_discente:casos_de_uso:ensino:emitir_historico www.info.ufrn.br/wikisistemas/doku.php?id=desenvolvimento:especificacoes:sigaa:portal_do_discente:casos_de_uso:ensino:emitir_declaracao_de_vinculo	No	No
Grades	www.info.ufrn.br/wikisistemas/doku.php?id=desenvolvimento:especificacoes:sigaa:portal_do_discente:casos_de_uso:ensino:consultar_minhas_notas	No	Yes
Schedule	www.info.ufrn.br/wikisistemas/doku.php?id=desenvolvimento:especificacoes:sigaa:portal_do_discente:casos_de_uso:ensino:emitir_atestado_de_matricula	No	Yes

Table VI. SIGAA mobile selected functionalities document

incorrect invasions performing refactoring. At the end of this phase, we had an architecture for mobile application and a services layer in SIGAA Web.

After the design phase, SIGAA Mobile was developed and we moved on to the Metamorphosis deployment phase described in Section 4.3. We evaluated the need to publish this application on Google Play and decided to use this app market instead of using an in-house solution. The reason for this decision was mainly that the cost of

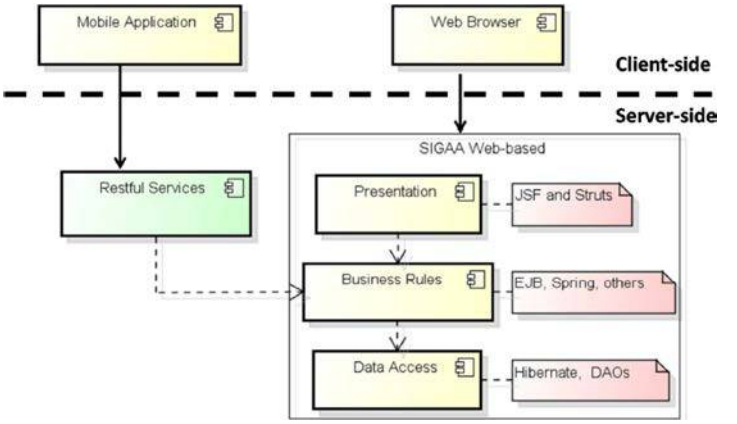


Figure 10.
Solution to integrate existing Web-based SIGAA with new mobile application

maintaining an in-house solution was higher than the cost of publication in the applications market. In addition, we had a lot of potential users using the Google Play market. After SIGAA Mobile was finally released in Google Play, the communication agency (AGECOM), which is the Communication Agency of UFRN, did an intensive publicity about it and the numbers of installations grew significantly. The SIGAA Mobile deployment document is presented in Table VII.

5.3 SIGAA mobile

SIGAA Mobile, whose main screens are presented in Figure 11, was developed using the Android platform and the activities in the Metamorphosis process, described in Section 4, which resulted in the architecture presented in Figure 12.

The View layer contains all Android activities, i.e. components which interact directly with the user presenting the graphical interface and manipulating the user events. It uses a layer of abstraction for the business rules that are hosted in the server called Business Delegate. This layer uses a communication channel which implements the REST pattern to communicate with the server-side of the system. Moreover, it manipulates the Cache Data Access Layer, storing and recovering data, depending of the connectivity status, to allow offline use capability.

Nowadays, SIGAA Android is installed in about 9,000 devices (active installations), whose growth is presented in Figure 13. It was uploaded to Google Play on April 25th, 2012, and the download number is increasing ever since.

Table VII.
SIGAA mobile deployment document

Description	Mobile market	Link to download
SIGAA Mobile is a mobile enterprise application developed by UFRN that provides academic information from SIGAA Web	Google play	https://play.google.com/store/apps/details?id=br.ufrn.sigaa.mobile

Figure 11.
SIGAA Mobile main screens

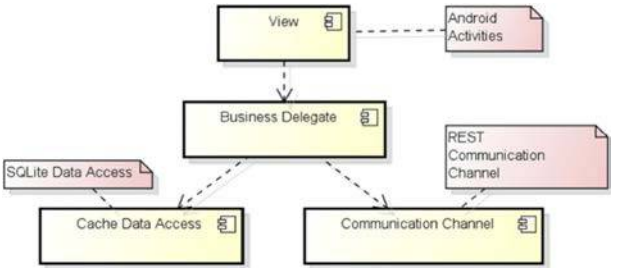


Figure 12.
Software architecture of Android SIGAA application

Figure 13.
SIGAA Android active installations

Figure 14.
SIGAA Android logins

We used SIGAA log infrastructure to discover the average daily access and most used functionalities. SIGAA has a database log controlled by an asynchronous process of persisting information about every user's operations. Analyzing daily access logins into SIGAA Android, we discovered that this application has about 2,350 daily logins. We noted the increase in login numbers at the beginning and the end of the academic activities period, as presented in the graph in Figure 14. For example, in vacations periods, the number of access decreases, but immediately before and immediately after it, the number of access increases.

6. Conclusions and future works

The activities of the Metamorphosis process were proved useful in terms of MEAs development from existing Web information systems. However, to be more confident of their efficiency, it is important to apply them in other similar projects. Based on these experiences, we intend to improve this process presenting more information, such as codes and how a particular functionality can be adapted for a MEA, including providing details of how inputs can be adapted, possible differences in the workflow in both versions, affected components and other architectural details related to this process.

We believe that as more information is collected applying the Metamorphosis process in other cases, we will be able to develop architectural solutions to the context of MEAs based on existing Web systems, specifically regarding to design: architectural patterns, frameworks and reusable components.

Note

1. This paper is an extension to the paper titled "MetamorphosIS: A Process for Development of Mobile Applications from Existing Web-Based Enterprise Systems" published on 14th International Conference Computational Science and Its Applications – ICCSA 2014.

References

Aquino, G. and Barroca Filho, I. (2013), "SIGAA mobile a successful experience of constructing a mobile application from an existing web system", *25th International Conference on Software Engineering & Knowledge Engineering*, Boston, MA, pp. 510-516.

Ayob, N.Z.B., Hussin, A.R.C., Dahlan, H.M. (2009), "Three layers design guideline for mobile application", *Proceedings of the 2009 International Conference on Information Management and Engineering, IEEE Computer Society (ICIME '09), Washington, DC*, pp. 427-431.

Barroca Filho, I.M., Aquino, G.S. (2014), "MetamophosIS: a process for development of mobile applications from existing web-based enterprise systems", *14th International Conference Computational Science and Its Applications (ICCSA)*, Guimarães, 30 June-3 July.

Bass, L., Clements, P. and Kazman, R. (2013), *Software Architecture in Practice*, 3rd ed., Addison-Wesley.

Buschmann, F., Meunier, R., Rohnert, H., Sommerlad, P. and Stal, M. (1996), *Pattern-Oriented Software Architecture: A System of Patterns*, John Wiley & Sons, New York, NY.

De Silva, L. and Balasubramaniam, D. (2012), "Controlling software architecture erosion: a survey", *Journal of Systems and Software*, Vol. 85, pp. 132-151.

Ellison, S. (2010), "Worldwide and US mobile applications, storefronts, and developer 20102014 forecast and year-end 2010 vendor shares: the 'application' of everything", available at: www.idc.com/research/viewdocsynopsis.jsp?containerId=225668

Gartner (2013), "Gartner says worldwide mobile phone sales declined 1.7 per cent in 2012", available at: www.gartner.com/newsroom/id/2335616

Gartner (2014), "Gartner says worldwide traditional pc, tablet, ultramobile and mobile phone shipments on pace to grow 7.6 per cent in 2014", available at: www.gartner.com/newsroom/id/2645115

Giessmann, A., Stanoevska-Slabeva, K. and Visser, B. (2012), "Mobile enterprise applications – current state and future directions", *45th Hawaii International Conference on System Science*, *IEEE Press, HI*, pp. 1363-1372.

Grønli, T.-M., Hansen, J., Ghinea, G., Younas, M. (2014), "Mobile application platform heterogeneity: Android vs Windows phone vs iOS vs refox os", *IEEE 28th International Conference on Advanced Information Networking and Applications (AINA)*, pp. 635-641.

Harrison, R., Flood, D. and Duce, D. (2013), "Usability of mobile applications: literature review and rationale for a new usability model", *Journal of Interaction Science*, Vol. 1 No. 1.

Hernandez, I., Viveros, A. and Rubio, E. (2013), "Analysis for the design of open applications on mobile devices", *International Conference on Electronics, Communications and Computing (CONIELECOMP),* pp. 126-131.

HSIEH, M.-Y., Lin, H.Y., Yeh, C.H., Li, K.C. and Wu, B.S. (2012), "A mobile application framework for rapid integration of ubiquitous web services", *9th International Conference on Ubiquitous Intelligence & Computing and 9th International Conference on Autonomic & Trusted Computing (UIC/ATC)*, pp. 136-142.

IDC (2010), "IDC forecasts worldwide mobile applications revenues to experience more than 60% compound annual growth through 2014", available at: www.idc.com/about/viewpressrelease.jsp?containerId=prUS22617910

Kitchenham, B. and Charters, S. (2007), "Guidelines for performing systematic literature reviews in software engineering".

Kolici, V., Xhafa, F., Pinedo, E., Nunez, J. (2013), "Analysis of mobile and web applications in small and medium size enterprises", *8th International Conference on P2P, Parallel, Grid, Cloud and Internet Computing*, Compiegne.

Kolokolov, V., Baumann, P., Santini, S., Ruehl, S.T. and Verclas, S.A.W. (2013), "Flexible development of variable software features for mobile business applications", *Proceedings of the 17th International Software Product Line Conference Co-located Workshops*, *ACM, New York, NY*, pp. 67-73.

Nayebi, F., Desharnais, J.-M. and Abran, A. (2012), "The state of the art of mobile application usability evaluation", *25th IEEE Canadian Conference on Electrical & Computer Engineering*, *Montreal.*

Nosseir, A., Flood, D., Harrison, R. and Ibrahim, O. (2012), "Mobile development process spiral", *7th International Conference on Computer Engineering & Systems*, Cairo.

Picco, G.P., Julien, C., Murphy, A.L., Musolesi, M. and Roman, G.C. (2014), "Software engineering for mobility: reflecting on the past, peering into the future", *Proceedings of the on Future of Software Engineering*, *ACM, New York, NY*, pp. 13-28.

Thebault, P., Decotter, D., Boussard, M. and Lu, M. (2013), "Embodying services into physical places: toward the design of a mobile environment browser", *ACM Transaction on Interactive Intelligent System*, ACM, New York, NY, p. 8.

Zamula, D., Kolchin, M. and Zamula, D. (2013), "MneMojno- design and deployment of a semantic web service and a mobile application", *14th Conference of Open Innovations Association (FRUCT)*, pp. 171-176.

Corresponding author
Itamir de Morais Barroca Filho can be contacted at: itamir.filho@gmail.com