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A Quality Evaluation of an Android Smartphone Application

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ABSTRACT

Smartphones are considered as the new generation of mobile devices. As the popularity of smartphones is increasing, many users tend to use various applications on them. Thus, it is imperative to devote much attention on the quality evaluation of these applications. This concern defined a research topic for Logica to work on quality issues of smartphone applications.

With the aid of ISO/IEC 9126 quality model, this thesis aims to evaluate the quality of a prototype which was designed and developed on Android platform. This prototype was a time management application based on Pomodoro technique.

This thesis performs the studies on reviewing relevant literatures from two viewpoints: identifying proper solutions to design and develop an Android application and determining product quality measurement of smartphone applications. Furthermore, structured interviews with smartphone application developers and quality team at Logica were used to collect more to address the above viewpoints. Once the prototype was developed, an experiment was designed and run to evaluate the usability of the proposed prototype.

The results of the thesis are the implementation of the proposed prototype on Android platform and the measurement of the prototype's usability. Results obtained from the experiment can lead us to resolve problems associated with usability and find solutions for its improvement.

KEYWORDS

Smartphone, Android, smartphone application, ISO/IEC 9126, software quality model, Pomodoro technique

1. INTRODUCTION

Software products play an increasingly important role in our life and every software product faces a set of quality issues that affect us in different ways. Over the past few years, software quality has become more essential in software engineering, therefore it is important for each software project to define its specific meanings of quality during the planning phase [10]. Standards like ISO can help us to provide a clear definition of quality for software projects. According to ISO 9000, quality can be defined as "the totality of characteristics of an entity that bear on its ability to satisfy stated or implied needs [22]".

In particular, mobile phones which comparing to other technological devices, have been adapted faster to our life, are among one of the fastest growing communication technologies. With the rapid progress of mobile phones, the functionality of these devices is improving. Mobile phones are now able to perform a number of functionalities including connectivity with other devices, ability to take high resolution photographs and video recording. These devices are often referred as smartphones. Smartphones are not only mobile phones but also complicated devices like mini computers [8, 27, 4].

Lately, by enhancing the functionality of smartphones, the quality issues become more critical. Consequently, as smartphones grow in popularity, application stores become the focus of smartphone users and software companies. That implies more quality attention is expected in smartphone application field.

These concerns pose strict demands for software development companies, in this thesis exemplified by Logica.. Logica is a business and technology service company that delivers business consulting, systems integration and outsourcing across all industries and business functions [20] and uses new mobile technologies (currently smartphones) to deliver its services.

In this study the main focus has been placed on evaluating the quality of a prototype which was designed and developed for Logica Company. The implementation resulted in a time management application according to the Pomodoro technique on Android platform. Pomodoro is a time management technique which was created by Francesco Cirillo in 1992.

The interested parties of this thesis can be companies that are looking into the future of smartphone applications and the developers who are willing to write applications mainly in Android environment.

The rest of the report is organized as follows:

Section 2 summarizes the related literature background for the current work. Section 3 addresses the problem statement in this research and defines the research question. Section 4 describes the research methodology used to address the research question. Section 5 reviews the prototype specifications. In this section, required functional and non-functional requirements for the designed prototype are reviewed. Section 6 is dedicated to select the most relevant quality attributes in order to define a quality model for the designed prototype according to ISO/IEC 9126. In this section, the proper metrics were defined to support the quality measurement. Section 7 describes the experiment which evaluates the usability of the prototype according to the defined metrics in section 6. Section 8 finalizes the paper by giving a conclusion.

2. PROBLEM IDENTIFICATION

2.1 Project Outline

The main goal of this work is to assess the quality of a prototype developed on Android platform. The prototype was designed based on the Pomodoro technique. Pomodoro is a time management technique which helps users to manage the time in an efficient manner.

The main goal of this thesis is to design and develop the prototype in order to measure the product quality according to quality attributes chosen based on ISO/IEC 9126 quality standard.

The following tasks were initially formulated for this thesis project:

1. Literature study in the domain of smartphone technology and software product quality
2. Designing and implementing of a prototype supported by Android platform
3. Defining a quality model for the prototype
4. Designing an experiment to evaluate usability of the prototype.

2.2 Research Question

The research question of this thesis is:

How to evaluate the quality of a time management application developed for Android?

The research question arose from Logica's need to have a quality model in order to evaluate the quality of smartphone applications.

3. BACKGROUND

This section provides a concise introduction on the underlying concepts of this work in order to give the reader background knowledge based on relevant literature reviews.

3.1 Smartphone Technology

Smartphones are considered to be cell phones which can provide more functionality and computation abilities than basic mobile phones but less functionalities than laptops. Most smartphones support full featured e-mail facilities, cameras, WiFi connectivity, and comprehensive user interface such as touch screen, embedded GPS system and interface for installing new applications.

The operating systems run on smartphones are the fundamental parts of software system. The operating systems which have been designed for these smart devices should be energy efficient with fewer memory footprints and more optimizations [29]. S.P. Hall and E. Anderson [26] introduce the most common operating systems in the market as Blackberry, Windows Mobile, iPhone, Symbian and Android. According to their views, smartphone software development relies on these operating systems.

With the rapid progress of smartphones, global smartphone shipments are expected to increase to 506 million units in 2014 from 246.9 million in 2010. Among them, shipments of iPhone and Android have accelerated by launch of HTC Hero and Nuxus One and iPhone 3GS [31].

3.2 Android

Android is the first open, complete and free mobile phone operating system and development platform. Android was developed by The Open Handset Alliance, a group of over 30 companies led by Google. By announcing Android, Google aims to offer a more flexible and feature-rich platform to attract more community of developers and use those developed applications to convince customers to purchase Android handsets [21, 19].

Android is considered as a set of softwares for mobile devices that contains an operating system, middleware and key mobile applications. Android covers different features such as application framework, Dalvik virtual machine, integrated browser, optimized graphics, SQLite for structured data storage, media support for common audio, video and image format, GSM technology, Bluetooth, EDGE, 3G, and WiFi, camera, GPS, compass, and accelerometer and rich development environment [3,18].

The architecture of Android, similar to any other operating system has a hierarchical structure. It is divided into four main layers that consist of application layer, application framework layer, system layer and Linux runtime core layer (Figure 1).

Application includes a set of core applications including email client, calendar, web browser, map application, SMS application, contact application, messaging application etc [3, 18, 21].

Application Framework which is the base of developing applications in Android has been designed to ease the reuse of component and allow components to be replaced by users [3, 18, 21].

Libraries are set of C/C++ libraries used by various component of Android system [3, 18, 21].

Android Runtime includes a set of core libraries and Dalvik virtual machine. Core libraries provide the functionalities which are available in Java programming language. Dalvik virtual machine is like a translator between the application side and the operating system. Every Android application runs in its own process, with its own instance of the Dalvik virtual machine [3, 18].

Linux Kernel performs as an abstraction layer between the hardware and Android software. Android uses Linux version 2.6 for core system services such as security, memory management, process management, network stack, and driver model [3].

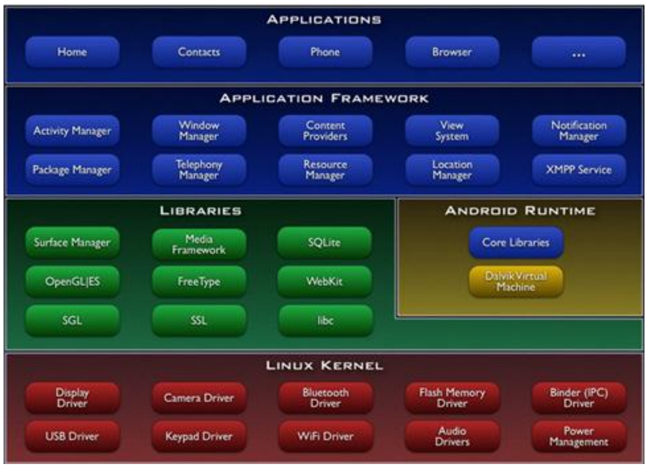

Figure 1. Android Architecture [3]

3.3 Smartphone Applications

Smartphone applications are developed and run on handled devices such as smartphones and perform specific tasks for users. These applications are installed on the device by manufactures or downloaded by users from global smartphone application markets. In last few years, mobile application markets have grown rapidly and more smartphone application developers have stepped into this new market.

Apple's App store can be mentioned as the first smartphone application market. The launch of App store created such an unbelievable hype in smartphone industry that the other mobile manufactures started creating their own application stores. At present, the most common mobile markets are Apple's App store, Google Android Market, Microsoft Windows Market, Nokia OVI and RIM Blackberry App World [13].

3.4 Pomodoro Technique

Pomodoro is a time management technique which was created by Francesco Cirillo in 1992. The aim of Pomodoro Technique is to provide a simple tool to improve productivity. Three main characteristics of this technique are summarized as different way of seeing time, better use of mind and easy-to-use [24, 6].

The basic unit of work in the Pomodoro technique is split in five steps [24, 6]:

- Choose a task to be accomplished
- Set the timer to 25 minutes
- Work on the task until the timer rings, then put a check on your sheet of paper
- Take a short break about 5 minutes
- Take a longer break for every four 25 minutes [6, 24].

It is worth mentioning that Pomodoro is an iteration technique consisting of five stages. The phases are the following.

- **Planning** at start of the day to decide on day's activities
- **Tracking** throughout the day to gather data on effort expended on each activity
- **Recording** at the end of the day to compile an archive of daily observations
- **Processing** at the end of the day to transform the data into information
- **Visualizing** at the end of the day to present the information in a format that facilitates understanding and clarifies paths to improvement [6].

3.5 ISO/IEC 9126

The ISO/IEC 9126 is one of the well-known quality standards available in software engineering area. This standard which has been defined by International Organization for Standardization (ISO) is used to evaluate the software product quality. The ISO/IEC 9126 is divided into three parts: external metrics, internal metrics and quality in use [5, 25].

The attributes which are measured during the development process are referred to as internal whereas the external behaviors are measured during testing process. Finally, quality in use stresses in user's view of final product quality in real condition [25, 16]. Figure 2 shows the relationship between different types of ISO/IEC 9126 parts.

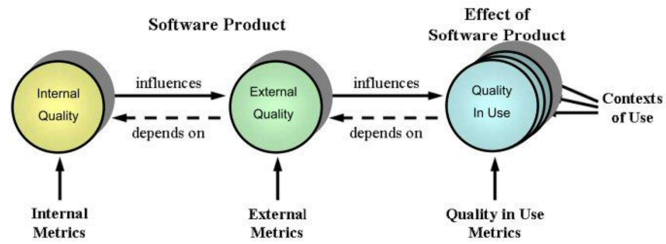

Figure 2. ISO/IEC 9126 Quality Model

ISO/IEC 9126 presents hierarchical structure in order to evaluate internal/external quality of the software product. The highest level of that structure classifies the software quality attributes in six main characteristics which each of them describes an aspect of software quality [28]. These main characteristics can be summarized as functionality, reliability, usability, efficiency, maintainability and portability. Each of these characteristics is further broken down into sub-characteristics, serving to detail of view point when analyzing software. The sub-characteristics are illustrated in Figure 3.

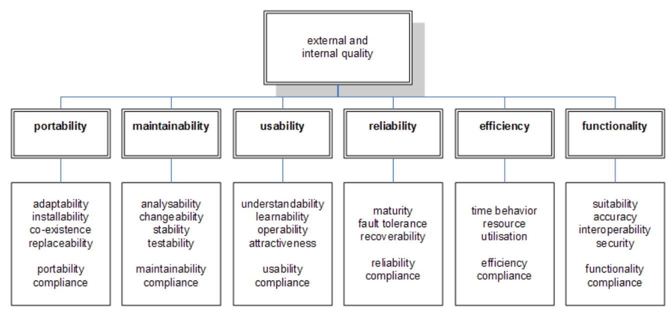

Figure 3. ISO/IEC 9126 External and Internal Quality Attributes

4. RESEARCH METHODOLOGY

4.1 Methodology

The research was started with formulating the research problems in two concepts-development issues and quality issues. After discovering problems in mentioned areas, as recommended by Kumar [17], secondary data were collected by reviewing relevant literature. In the first step of this work, our focus was on development issues; therefore the research was started with literature review on Android architecture and the most appropriate ways of developing the prototype on Android platform. Also inspired by Kumar [17], secondary data were obtained through interview with domain experts such as software architecture and smartphone application developers in mobility group at Logica.

After each interview, the interview questions were reviewed and edited in order to improve the shortage of designed questions. Editing the question in each phase, led us to the research question goal.

Eventually, the possible solutions were analyzed and a prototype was developed in order to validate the results through applying the proposed quality solution.

After developing the prototype, in the next step, deep literature review was started to achieve the most common problems the prototype faced with. Following the literature review, the quality problems related to the designed prototype were identified, but also other problems originating from the nature of mobile phones were found out. The next step was choosing a quality model in order to measure the quality of the prototype. In order to choose a quality model several models were studied and some interviews were conducted with quality team from Logica. Finally ISO/IEC 9126 was selected as it was the quality standard followed by Logica and it was one of the most recent quality standards suggested by literatures. After selecting ISO/IEC 9126 as quality standard, the quality characteristics related to the prototype were analyzed and a quality model for the prototype was proposed.

Lastly, an experiment was conducted to evaluate the usability of the prototype according to the defined quality model. This empirical study was designed in order to validate the study result.

4.2 Data Collections

The following data sources were used through the study:

- Literature review was done especially in the first step of the research. This literature study was conducted to cover both development issues and quality issues. In the development phase, literature studies helped us to have a better view about Android architecture and smartphone technology. In the quality phase, literature review clarified the most critical quality issues in smartphone applications.
- Interviews were conducted with the mobility group and quality team at Logica. In the first phase of the project, the interviews with software architecture and smartphone application developers provided us with better architecture design and development method solutions. On the other hand, conducted interviews with the quality team helped us to figure out which quality model is more appropriate for Logica quality team. Also they helped us to prioritize the related quality characteristics for the prototype.
- Regular meeting with industrial supervisor from Logica and academic supervisor at IT-university were aimed to design and develop the Pomodoro prototype, propose the quality model, design the usability experiment and assure that the research is on the right track.

4.3 Data Analysis

Once the data were collected, analysis was started. After each interview, the data were analyzed and categorized in different groups. In addition, editing the interview procedure was done on the interview questions to improve the quality of data for analyzing.

In this work, firstly the notes taken during the interviews were reviewed and classified in different groups. The most important categories can be mentioned as prioritizing the features, analyzing the proper integration methods with the service provider, user interface design, identifying the most important quality attributes and their priorities. Categorizing the collected data eased the data analyzing in next step. Additionally, it helped us to be sure about existing of enough data in all needed areas.

Generally, the most important outcome of the literature review and interviews is that we got knowledge about how to develop an Android application according to the company's need, how to select the quality standard, how to choose the most important quality attributes and their priorities for the company.

5. Prototype Specifications

5.1 Prototype Description

As a proof of concept an implementation was done to support the quality evaluation. Furthermore, the company could benefit eminently from evaluating new technologies and platforms from the development perspective.

In development part of this work, a sample tool was developed on Android mobile platform. The mentioned tool could integrate with a central service provider using web oriented architecture. The service provider was considered as the data owner of the prototype.

The proposed prototype illustrates how user can manage the time according to the Pomodoro technique on his personal smartphone. To start the application, user needs to login in order to connect to the service provider. Afterwards, user defines a list of activities which are categorized to three groups of inventory list, to-do today list and urgent list. For each defined activity, user starts the Pomodoro timer which is set to default 25 minutes. According to the Pomodoro technique, each 25 minutes is considered as one Pomodoro. The timer alerts the user when it reaches zero. After finishing one Pomodoro, the time will be stopped and a break count up starts for 5 minutes. User needs to repeat the Pomodoros until finishing the activity. The finished activity will be marked and archived as a done activity. Moreover, the timer informs user every four Pomodoro for a longer break.

Similarly, user can edit the activity lists and keep track of number of Pomodoros executed for an activity. Moreover, length of Pomodoro time and break time can be changed by user.

5.2 Collaboration with other master theses

The whole project was done by eight students from Chalmers University and IT university of Gothenburg. The students were divided to four groups according to their interests and skills. The entire project resulted to develop the Pomodoro tool on different platforms (Figure 4). In this case, as extension to the client application, a central service provider was developed which the other clients could integrate with it. Therefore, the user could switch between the developed applications on his computer to his phone at same time without any data losing.

The teams can be introduced as the following way:

- **Android**
  This part which is the main focus of the thesis, was done by me and Erik Söderberg, a student of Software Engineering and Technology at Chalmers University.
  The cooperation between Erik and me resulted to develop the Pomodoro product on Android platform. The result which is run on Android Developer HTC Phone was released to end users as an Android application.

  Within the whole Android part of the project both of us contributed equally to develop the prototype although in this thesis report only my work results which focus on quality evaluation of the prototype are described.

- **iPhone**
  Similar to Android team, iPhone team developed the Pomodoro application on iPhone platform. The result was released as an iPhone application.

- **Web Stripes**
  This team focused on developing a web application using Stripes. "Stripes is a presentation framework for building web applications using the latest Java technologies" [23]. The development resulted in a Pomodoro web application tool.

- **Service Provider**
  The primary goal defined for this team was designing and developing a public API (Application Programming Interface) for the other teams. This team developed a service provider using REST (Representational State Transfer). REST is an architecture style to describe how distributed data objects can be defined and addressed, stressing the easy exchange of information by using protocols of World Wide Web [7]. In opposite to the other teams, this team was not involved with any interface concept since it was all about integration and invisible Cloud computing.

- **Flex/Air application**

  This part was canceled at the beginning of the project according to the company policies.

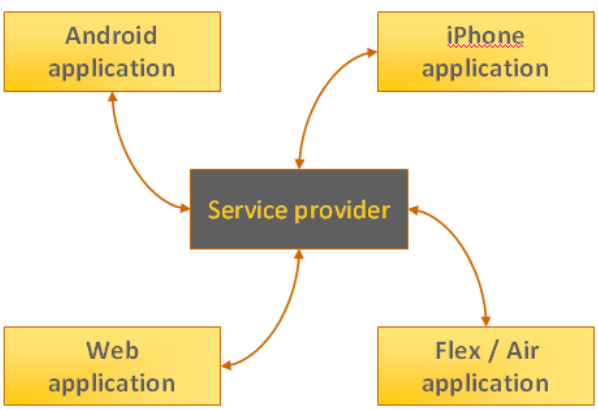

Figure 4. Project Result

5.3 Tools and Technology

The following software tools and technologies were used during the development phase:

- Microsoft Visio 2007- as a modeling tool
- SQLite- as a database
- Java- as a programming language to implement the prototype
- Android Platform- as an development Android device platform
- MS Excel- as a tool to store data collected from the experiment study.

5.4 Functional Requirements

The current section gives a description of the final prototype functionality which can be categorized in five main features. Further, each feature is divided into some sub-features.

Execute a Pomodoro

- Defining a set of activities
- Starting the Pomodoro timer with default time of 25 minutes
- Alerting user when the timer reaches 0
- Stopping the timer
- Informing user every 4 Pomodoro for a longer break
- Marking activity as done
- Demonstrating history of marked activity

Activity List

- Create, read, update and delete operations for To-Do Today list
- Create, read, update and delete Activity Inventory list
- Create, read, update and delete Urgent list
- View To-Do Today list
- View Activity Inventory list
- View Urgent list
- Moving Activities from To-Do Today list to Inventory list
- Moving Activities from Inventory list to To-Do Today list
- Moving Activity from Urgent list to To-Do Today or Inventory lists

Cloud Connection

- User authentication to the Cloud service
- Create, read, update and delete operations in the Cloud

Records

- Tracking number of Pomodoros and interrupts executed for each activity

Setting

- Changing the length of a Pomodoro
- Changing the length of break between Pomodoros
- Changing login information for the Cloud service

5.5 Non-Functional Requirements

The most essential non-functional requirements assigned for the designed prototype can be summarized in Table 1. They will be discussed in detail in Section 6.

Table 1. Non-functional Requirements

Non-functional Requirement	Importance
Functionality	Desirable
Reliability	Desirable
Usability	Essential
Efficiency	Desirable

6. QUALITY MODEL FOR THE PROTOTYPE

In this work, ISO/IEC 9126 was chosen as a quality standard to assess the quality of the designed prototype. The mentioned quality model was selected since it was the quality standard model at Logica. Measurement the quality of the prototype provided a quantitative description of the prototype. Finally, the results provided us knowledge to improve the product quality.

After selecting the proper quality model, the quality assessment of the prototype was started by considering developer's viewpoint and end user's viewpoint. Furthermore, it is worth mentioning that in this work, the focus of this quality measurement is on product quality rather than process quality of the product.

The first step to define a quality model for the prototype according to the Gafni's [10] research process was detection of quality problems that were related to the developed prototype. Except for the quality issues in the designed prototype, there were two other types of problems which affected the quality of the prototype.

The first group of problems originated from the nature of mobile devices such as small memories, short battery life, limited calculation and computation capabilities, tiny screen, small keyboard, low resolution and wide variety of devices which make it difficult for an application to adapt to all of them. The second group was related to network problems such as limited bandwidth, inconsistent connection stability, data transfer delays and security issues [10, 12].

According to the quality issues mentioned above, the quality of the prototype was measured taking into account three different aspects:

- Traditional measurement by fundamental metrics which are used for all information systems.
- Measuring the problems which originated from the mobile device characteristics.
- Measuring the network limitations which affect the quality of the prototype.

After considering the three groups of problems and conducting a deep study on the prototype features, and company's needs, a quality model was designed for the prototype. This has been done by choosing the relevant ISO/IEC 9126 quality characteristics for the prototype.

6.1 Quality Attributes of the Prototype

In this section, the most relevant quality attributes were selected for the developed prototype. This selection was done by considering the nature of mobile phones, the prototype characteristics and company's needs. In addition, the priority of the attributes was the other issue we needed to consider.

In the next phase of the measurement, the relevant quality metrics were selected and necessary validation was done. The quality evaluation process was based on Gafni's [10] research process, which consists of following steps:

(1) Detection of quality issues which affect the quality of the designed prototype
(2) Choice of ISO/IEC 9126 quality characteristics affected by the prototype quality issues
(3) Selection of metrics
(4) Quality measurement by applying the metrics on the prototype.

In order to define the quality attributes, several interviews were conducted with the quality team of the company. Firstly, we realized that ISO/IEC 9126 is the quality standard that the company uses for software product. Secondly, according to the interviews, the most important ISO/IEC 9126 quality characteristics and sub-characteristics were clarified for us. Moreover, study reviews were done on basic mobile phone characteristics that may affect the quality of the prototype. In addition, relevant metrics were introduced in order to measure the quality of the prototype.

Finally, four characteristics were selected to measure the quality of the prototype. Further, for each quality characteristics the related sub-characteristics were chosen. The following quality characteristics and sub-characteristics are described as follows:

Functionality is "the capability of the software product to provide functions which meet stated and implied needs when the software is used under specified conditions [15]". According to ISO/IEC 9126, functionality includes four sub-characteristics: suitability, accuracy, interpretability and security.

Sub-characteristics:

- *Suitability*- the capability of the system to provide an appropriate set of functions for specified tasks and user objectives [12].

  This sub-characteristic is important for the developed prototype, especially because of the mobile device limitations that cause difficulties to implement all the required features.

  Metric purpose
  Compare the number of the defined features to the number of the completely implemented features.

  Method of calculation
  1. At the design phase: count number of features to be included in the product;
  2. Deployment phase: count number of features delivered

- *Security*- the capability of system to protect information and data [12].

  It is important for the application to prevent unauthorized access to data while interacting with the service provider.

  Metric purpose
  Measure the usage degree of security mechanism, like authorization.

  Method of calculation
  1. Login in order to access the data in the service provider several times
  2. Calculate the ration between numbers of authorized access to the all access to the data - The higher the

number of the authorized access, the better the security is.

Reliability is "the capability of the software product to maintain a specified level of performance when used under specified conditions [15]". According to ISO/IEC 9126, reliability includes three sub-characteristics: maturity, fault tolerance, recoverability.

Sub-characteristics:

- *Fault Tolerance*- the capability of the system to maintain a specified level of performance in cases of software faults or of its specified interface [12].

  Considering the application interacts with a service provider, there is high risk of various faults because of losing access to the service provider. That is the reason why this sub-characteristic was chosen for evaluation of the prototype.

  Metric purpose
  Measure the response time to get information from the cache.

  Method of calculation
  1. For each task:
     a. Perform the task minimum 5 times
     b. Receive the data from the service provider
     c. Store the data in the device memory
     d. Retrieve the data locally
     e. Calculate the average time to get data as output
  2. Calculate the maximum value of the average time to get data as output for all the tasks.

- *Recovery*- the capability to recover data affected in case of failure. The prototype needs to have fault tolerance to recover data whenever network connection lost [12].

  Metric purpose

  Measure the resumption number of transactions after disconnection from service provider.

  Method of calculation
  1. For each task:
     a. Perform the task minimum 5 times
     b. Count the resumption number of transaction when it is disconnected from the service provider.
     c. Calculate the mean value – average resumption time
  2. Calculate the maximum value of the average resumption time for all transactions.

Efficiency is "the capability of the software product to provide appropriate performance, relative to the amount of recourses used, under stated conditions [15]". According to ISO/IEC 9126, efficiency includes two sub-characteristics: time behavior and resource behavior.

Sub-characteristics:

- *Time behavior*- the capability of the system to provide appropriate response and processing time and throughput rates when performing its function, under state conditions [22].

  Time behavior is important because of the need to transfer data from the service provider in an appropriate time.

  Metric purpose
  Measure the response time to get information from service provider.

  Method of calculation
  1. For each task:
     a. Perform a task minimum 5 times
     b. Receive the data from the service provider
     c. Calculate the average time to get data as output
  2. Calculate the maximum value of the average time to get data as output for all the tasks.

Usability is "The capability of software product to be understood, learned, used, and attractive to the user, when used under specified conditions [15]". According to ISO/IEC 9126, usability includes three characteristics: understandability, learnability, operability.

Usability is one the most important characteristics for the designed prototype. This attribute is even more relevant when the prototype has wide users.

Usability can be threatened by the designed prototype in different ways:

- **Small screen.** This problem originating from the nature of mobile devices means to have fewer visible options at any given time.
- **Tiny Keyboard.** Text entry is difficult to operate with small keyboard and it causes more errors and slow operation.
- **Network Limitations.** Although the network bandwidth has developed during the last few years, the bandwidth of wireless is still narrow therefore some problems arise when the amount of data must be transferred. Since the application interacts with the service provider, bandwidths limitation is considered here.

Considering the mentioned problems above and importance of the usability for the mobile devices, an experiment was designed to assess the usability of the prototype. The experiment was designed to evaluate only the usability of the prototype since this characteristic had the highest importance for the company.

Sub-characteristics:

- *Understandability*- describes the user’s effort to recognize the logical concept of the system and its applicability [12].
  Metric
  To evaluate the understandability an experiment was designed and ran.

- *Learnability*- the user’s effort for learning the application [12].

  Metric
  To evaluate the learnability an experiment was designed and ran.

- *Operability*- the user’s effort to operate the system and to control its operation [12].

  Metric
  To evaluate the operability an experiment was designed and ran.

Lastly, the defined metrics for the selected quality sub-characteristics are summarized in Figure 5.

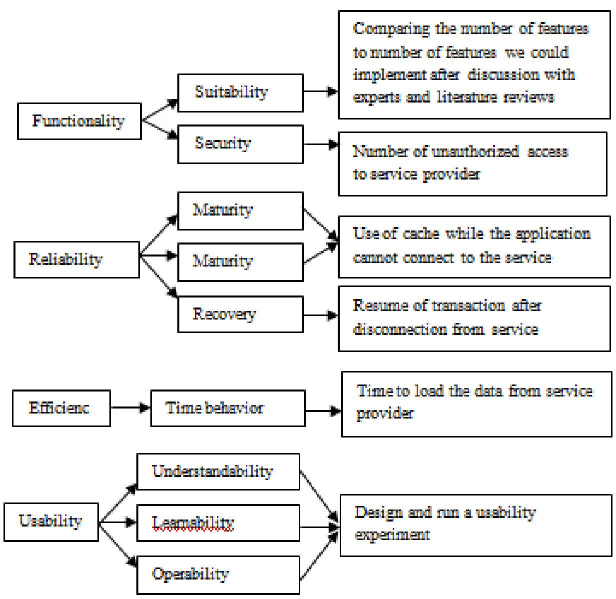

Figure 5. Metric mapped to quality charactristics

7. EXPERIMENT

7.1 Experiment Design

To evaluate the usability of the prototype, a control experiment was conducted. The experiment was done by applying some of the defined usability metrics described in section 6.

The goal of the experiment was to evaluate the usability of the developed prototype.

The details of the experiment are discussed more in the following sections.

7.1.1 Experiment Subject

The study reported here was carried out using two groups of people:

1- Expert users - smartphone application professionals
2- No-expert users - users without development background

The first group was selected from Mobility group at Logica. All the group members were smartphone application developers with experience of developing different smartphone platforms. Most of the group members had developed different smartphone applications on iPhone, Android and Windows Mobile platforms.

The second group was chosen from people without any background of smartphone application development.

Choosing two different groups of subjects helped us to evaluate usability from two points of view. Group of developers helped to improve the usability by noticing development problems and suggesting development solutions. On the other hand, popularity of the smartphone applications users motivated us to select second group as non-expert users. The members of this group were selected among a group of friends without any IT background. The number of participants in each group was five users.

7.1.2 Independent and Dependent Variables

In the experiment, two types of dependent and independent variables were defined.

There was one independent variable in this experiment, the usability of the prototype during performing tasks. Additionally, the dependant variables were:

I. Time to perform each task- the relevant time, measured in seconds, each user spent on given task
II. Total errors made for each task- the number of errors user made during performing each task

7.1.3 Instrumentation

The instruments in the study were a set of questionnaire in which five tasks were defined in order to measure the level of usability in the designed prototype. By performing the tasks by users, the usability problems found in the prototype were reported. The selected tasks contained the main features of the prototype which cover all phases of Pomodoro technique consisting planning, tracking, recording, processing and visualizing. The data gathered for each task included:

- Time to perform each task
- Total errors made for each task

The experiment procedure consisted of three phases. Before performing the tasks, in the first phase, an introduction was given about the Pomodoro technique. All the participants had to understand the Pomodoro technique before starting to perform the tasks. Furthermore, all subjects were given a description of their tasks. In the second phase, participants were asked to perform the defined tasks using the prototype. I was required to write the time when they started and finished each task. Finally, in the third phase, users were asked about the problems they experienced during performing each task. Moreover, users needed to login before starting the first task in order to access the main page of the application (Figure 6, 7). The defined tasks were as follows:

Task1- Create lists of activities: In this task, users first needed to plan the activities which they decided to do during the day. In order to provide the same situation for all the users, a list of activities was prepared. The written activates in this list were divided into three categories of inventory, to-do today and urgent activities. The purpose of writing the activity sheet was that the users have prepared lists of activities before they start to create activity list in the prototype. Therefore they did not spend time for thinking about which activities they wanted to enter to the lists. Further, users were asked to create list of activities in three categories of inventory, to-do today and urgent lists according to the given activity sheet.

In this task, users created activities in different tabs by clicking on the create button and typing the activity name in related category.

After finishing the task, user had a categorized list of activities in the three different inventory, to-do today and urgent tabs.

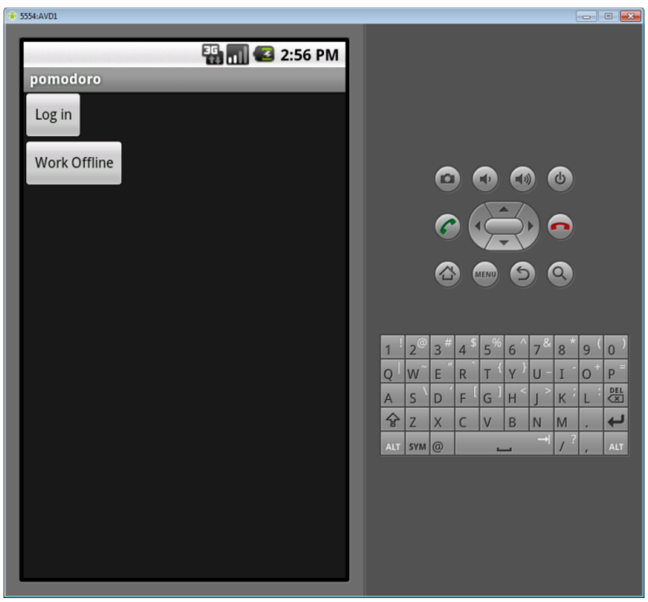

Figure 6. Log in to the prototype

Task2- Setting: In this task, users were asked to change the Pomodoro timer length and break length.

In order to perform the task, users found the setting page, entered the new numbers in Pomodoro length and broke length fields and saved the setting by clicking on save button.

Task3- Run Pomodoro: In this task, users were asked to start a Pomodoro for the selected activity.

To perform this task, users selected an activity from to-do today tab and clicked on start Pomodoro button to go to the Pomodoro page. In the Pomodoro page users started the timer by clicking on start Pomodoro button. After the timer reached zero, users could mark the selected activity as done.

Task4- View archive list: In this task users were asked to view the history of the activity which was marked as done in the previous task.

To perform this task, users found the archive list and clicked on the activity which marked as done. By clicking on the finished activity, users could view the number of Pomodoros which they spent on it.

The purpose of this task was that users could observe the number of Pomodoros spent on an activity.

Task5- Edit activity list: In this task, users were asked to edit the activity name.

In order to perform this task, users clicked on the edit button on activity list, entered the new name for the activity and saved the changes.

7.1.4 Analysis of Experiment Results

To assist the final measurement, the following data were collected for each participant:

- Number of errors user made for each task
- Time spent for performing each task

These data were collected for two groups of subjects separately. The reason for saving the data for each group was to determine whether both groups of subjects have the same average values. Having this type of analysis firstly helped the company to calculate how much effort is needed to launch the prototype after internal use in the company for a while. Additionally, having similar error rate from different groups of subjects clearly illustrated usability problems.

The first analysis which is shown in Figure 8, demonstrates the average number of errors which were made during performing each task. As shown in the figure, the most number of errors were related to task3. The reason was that to start the Pomodoro users needed to select the activity in related activity list and then start the Pomodoro. Most of the users had difficulties to find the Pomodoro button. The second most common errors were reported during performing task 4. In this task, users were confused where to see the history of the activity.

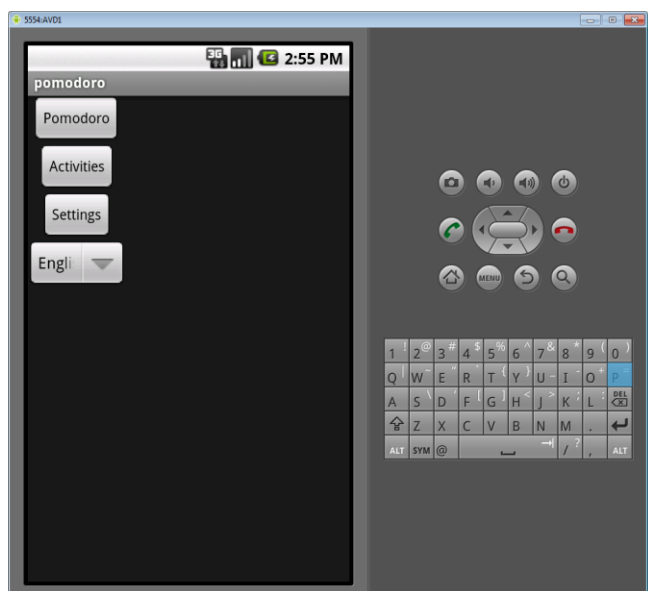

Figure 7. Main page of the prototype

It can also be seen in Figure 8 that the average number of errors in performing task3 was almost the same for both group of subjects.

It shows that none of the groups had good results in performing the mentioned task therefore serious attention is needed to improve the design of this task. Furthermore, the difference between numbers of errors for task4 shows that non-expert users had more challenges during performing the task. It can be concluded that technical knowledge helped the expert users to find the history page easier.

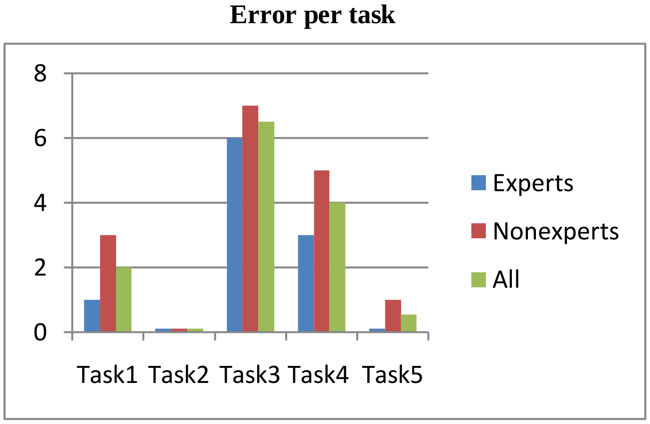

Figure 8.Average errors per group and for all users

Figure 9 shows the average group time per task and the total average time for all users. In addition, the expected time was calculated by performing the same tasks by me. The expected time for each task was calculated by adding extra seconds, depending on the complexity of the task. It can be seen that the most time was spent on task1 and task5. The observation during performing these tasks showed that the user spent most of the recorded time for text entry during performing both tasks. This problem arose from the uncomfortable use of the small keyboard which made the text-entry difficult for the users. The other time consuming task was task3. This problem, which was discussed in figure 8, originated from the mistakes users made to find the Pomodoro button.

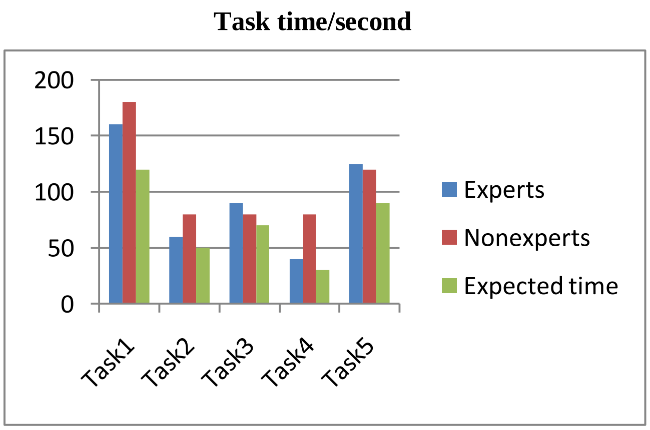

Figure 9. Average time per group

Comparing the recorded time for each group of subjects showed that the users with better typing skills could complete the task faster. Thus, in this case the comparison between two groups is useless.

7.1.5 Discussion

After performing each task by the users, they were asked about the usability problems they experienced during performing the tasks. Users' answers and analysis of the collected data during the experiment helped us to develop a set of usability suggestions in order to improve the prototype usability. The list of the considered suggestions is given bellow:

- Adding a Pomodoro button on the main menu:
  Due to the difficulty to find the Pomodoro button, a Pomodoro button can be added on the main menu. In order to access the activities from Pomodoro page, a link to the activity lists is necessary.
- Considering a separate list for done activities:
  Due to the number of errors users did during performing task 4, it can be seen that finding the history was challenging for users. Instead of showing the done activities in the inventory activities, it is better to consider a separate list for it.
- Adding a user manual:
  Adding a user manual can help users to clearly understand the prototype.
- Adding a link to Pomodoro web page in order to understand the Pomodoro Technique.
- Having a sorting feature:
  By increasing the number of activities, having a sorting feature can help user to find the activity in related list easier.
- Deleting the old activities:
  It is necessary to add a feature in order to delete the old activities in the lists when the memory is full.
- Having default values and choices:
  Having default values and choices for fields instead of text-entry can minimize the textual input errors and the time spent for text-entry.

8. CONCLUSIONS AND FUTURE WORK

Rapid progress of mobile phone technologies has formed a new generation of mobile devices - smartphones. As the popularity of such phones is growing, it has turned to be of a critical importance for developers to select a proper quality model for smartphone applications.

The main focus of this thesis was on designing and developing a prototype on Android platform with the goal of evaluating quality of the designed prototype. The product quality assessment process was conducted according to ISO/IEC 9126 quality model. Through identification of the quality issues in the designed prototype and selection of the applicable quality characteristics in ISO/IEC 9126, proper metrics were defined to measure the quality of the prototype.

During discussions with our industrial partner – Logica - usability was nominated as the most important quality characteristic. In order to measure the usability of the prototype, an experiment was designed run according with users with different backgrounds.

The results of the experiment led us to selecting the most problematic parts of the prototype and proposed quality improvements. Usability data collected during the experiment and interviews showed that despite usability problems, the designed prototype could assist users to manage the time according to Pomodoro technique on their personal smartphones.

Additionally, we believe that there still is some space for improvement which can be done as future work in this study. For instance a possible research track can be attempting to enhance user interface efficiency by selecting proper Android user interface elements. Next, more solutions are needed in order to use the cache memory efficiency while user lose network connection. Finally, the research can be expanded to adapt the metrics mapped to quality characteristics for other mobile devices such as cellular phones and Personal Digital Assistance (PDA) devices.

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