Towards a Process for NFRs Evaluation in IoT Applications

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Abstract. *The Internet of Things (IoT) is a paradigm characterized by a variety of objects that interact with each other using the internet to achieve common goals. IoT applications are more and more present in our lives, either in our homes, or on the streets, or in our work environments. These applications bring new Non-Functional Requirements highly related to the user interaction quality, such as context-awareness, synchronicity, and calmness. The evaluation of these NFRs can be challenging, because we may have to take into account qualitative and quantitative aspects. In this way, the evaluators can be confused about the steps they need to follow and the best order to perform the NFRs evaluation. After conducting a systematic mapping study about the NFR evaluation in IoT applications, we could not find a process that systematizes these activities step-by-step. Therefore, this paper proposes a process for evaluating non-functional requirements in IoT applications. This process divides the quality evaluation into two aspects, qualitative and quantitative, to capture quality measurements and subjective aspects of the IoT applications. To verify whether the established process meets the evaluators' needs, we applied 2 questionnaires with the experts and, based on the obtained results, we made some adjustments and came up with a preliminary version of the process that is presented in this paper.*

1. Introduction

Internet of Things (IoT) systems are already inside our reality and have been applied to several areas, such as health, agriculture, urban mobility, and smart homes. The International Data Corporation (IDC) predicts that by 2025, the world will have about 55.7 billion connected devices worldwide, 75% of which will be connected to an IoT platform[Corporation 2020].

The concern about IoT's system quality is growing since they start to interfere directly in our daily lives and may provide bad experiences to their users or even compromise their physical integrity.

A way of assuring system's quality is through quality evaluations, where Non-Functional Requirements (NFRs) are evaluated. In fact, IoT applications bring several new and specific Non-Functional Requirements, for example, context-awareness, calmness, synchronicity, mobility, attention [Andrade et al. 2017]. These NFRs are highly related to user interaction quality. Therefore, it is important to take them into account when performing quality evaluations.

Evaluate these NFRs can be challenging, because we may have to take into account qualitative and quantitative aspects. There can be several alternatives to perform a quality evaluation, using different methods or software measures. We did not find any previous study that proposes an approach to guide evaluators in this task. Therefore, there is a need to establish a solution to guide evaluators in this endeavor. Then, our research question is: *How can we systematize the evaluation of NFRs for IoT applications, taking into account quantitative and qualitative aspects?*

Thus, to collaborate with the quality evaluation field, we have started to develop an NFR evaluation process for IoT applications. To cover the singularities of IoT applications, we combine in this process a qualitative and a quantitative evaluation. Also, our purpose is to combine previous studies with well established NFRs for IoT, qualitative methods and software measures to guide evaluators.

The reminder of this paper is divided as follows: Section 2 presents a theoretical background; In Section 3, we discuss existing studies related to this work; Section 4 discusses the methodology for building the preliminary version of the process; Section 5 describes the proposed process; Section 6 presents the next steps of the research, and finally, we detail our final considerations on Section 7.

2. Background

2.1. Internet of Things

IoT can be defined as a paradigm where smart objects interact in an environment through a wireless connection, being able to cooperate in providing services and achieving common goals [Atzori et al. 2010].

IoT can be also considered as an extension of Ubiquitous Computing [Carvalho et al. 2020][Gubbi et al. 2013], which refers to devices connected everywhere in such a transparent way that we will not realize they are there [Weiser 1991]. Thus, IoT applications inherit some features from Ubiquitous computing, such as mobility and context-awareness.

To enable fluid ubiquity, the Internet of Things system needs to have three components [Gubbi et al. 2013]:

- Hardware: sensors, actuators, and communication systems;
- Middleware: storage tools and on-demand computing for data analysis; and
- Presentation: easy-to-understand visualization and interpretation tools that can be accessed on different platforms and applications.

On the other hand, IoT applications have also some singularities, such as interconnectivity, heterogeneity, and the ability to provide services related to the objects [Patel et al. 2016]. Limitations related to these features diminish their potential and impact usability [Rowland et al. 2015]. Therefore, it is critical to ensure that these properties are performing as expected in IoT applications.

When developing an IoT application, it is important to be aware of its singularities from the beginning of the development cycle, since the requirements' elicitation stage, where the IoT specificities can appear as non-functional requirements.

2.2. Non-Functional Requirements

Non-functional requirements can be defined as a description of a property or characteristic that a software system must exhibit or a constraint that must be respected beyond the system's observable behavior [Wiegers and Beatty 2013].

NFRs have two aspects that need to take into account: they can be subjective and relative. Subjective, because they depend on the interpretation of who will evaluate them; and relative because non-functional requirements to be prioritized vary from system to system [Chung et al. 2012].

Quality characteristics are also known as a type of non-functional requirement and describe the product's characteristics in various dimensions considered necessary by stakeholders, such as security and usability [Wiegers and Beatty 2013].

According to The ISO/IEC 25000, the quality of a software product can be evaluated by systematically determining the degree to which it meets specific criteria. Thus, the quality characteristics (or NFRs) must be specified, measured, and assessed, if possible, using validated or widely accepted measures and measurement methods [ISO/IEC 25000 2011].

The 25040 division of The ISO 25000 standard [ISO/IEC 25000 2011] deals with software quality evaluation, establishing general requirements for software quality specification and evaluation and provides an evaluation process. However, this process is generic and may not cover all the features of a given system type. For example, in IoT applications, we need to look deeper at some aspects as synchronicity, interconnectivity, calmness and context-awareness. Thus, it is important to identify what changes when conducting quality evaluation for IoT applications.

3. Related Work

Quality evaluation for IoT applications is a topic that has received attention from the scientific community. In [Kim 2016], for example, the authors proposed a quality model for IoT applications and specific measures for this type of application.

In [Andrade et al. 2017], the authors discuss how we can benefit from the ubiquitous field of systems interaction evaluation to evaluate interaction with IoT applications, focusing on both systems' main differences and similarities. In [Bures et al. 2020], the authors present a set of quality characteristics for IoT applications which specifically emphasizes the aspects of security, privacy, reliability, and usability.

Regarding the user experience on intelligent environments, the authors of [Ntoa et al. 2021], propose a methodological and conceptual framework to support research, design, and evaluation of user experience in intelligent environments. In their framework they explain the parameters of user experience to be evaluated, indicating how to evaluate them and when is the best time to do it.

In a systematic mapping study [Paiva et al. 2021], we focused on understanding how the NFR evaluations are conducted for IoT applications. Our string search also included the terms "Ubiquitous systems" and "Pervasive systems", as they are highly correlated with the IoT applications field.

Regarding the artifacts for evaluating IoT applications, we identified 2 tools, 6 approaches, 1 method and 1 process [Ruiz-López et al. 2013] that were used during the reported evaluations. We noticed that most of the approaches, methods, and tools focused on the requirements' elicitation stage and not on evaluating if the IoT application meet the NFRs previously established.

In addiction, we only identified one process that evaluates whether the system meets its NFRs, the MD-UBI process [Ruiz-López et al. 2013].This process aims to support developers and evaluators in elicitation, representation, and evaluation of requirements, focusing on NFRs. However, as the process covers the entire software development life cycle, the system evaluation appears only as a step of the process. Therefore, the activities to be performed are up to the evaluator's choice. Also, his focus is not specific on IoT applications but on ubiquitous systems.

4. Methodology

The development of NFR Evaluation process had 3 stages, illustrated in Figure 1.

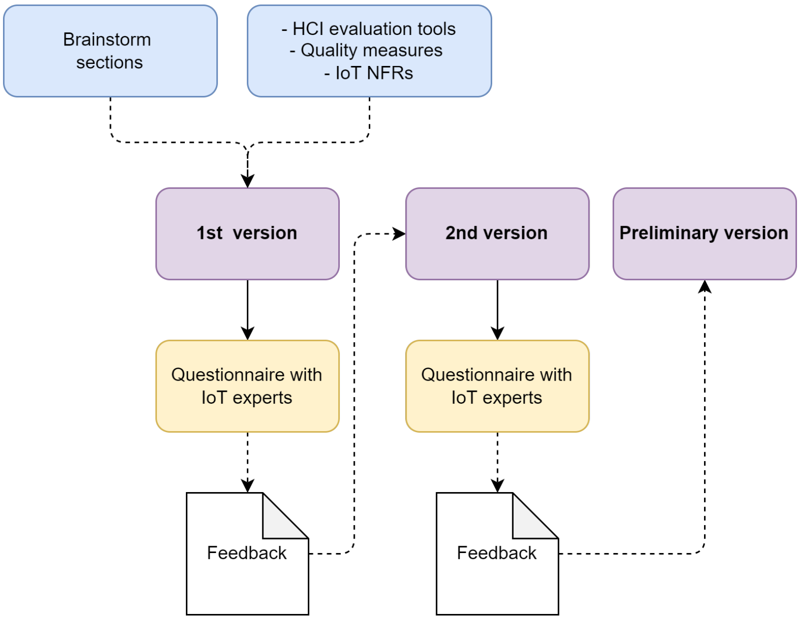

Figure 1. Methodology for the development of the process

In the first stage, based on our experience with IoT applications and quality evaluation, we conducted some brainstorming sections to elaborate an initial version of the process with a focus on the specific non-functional requirements for IoT applications, considering user experience (UX) and usability evaluation methods for the qualitative analysis, and IoT software measures for the quantitative evaluation. Figure 2 shows the initial version's steps.

To evaluate the process first version[1], we prepare a questionnaire for IoT experts, where the participants had to say if they agreed with the activities involved, the order in which they occurred, the coverage of the IoT singularities, and if they intended to use the process when evaluating an IoT application.

We obtained nine answers from IoT experts, 6 of whom are PhDs in Computer Science, and 3 are Ph.D. students in the same field. About the steps' order, 11% answered that it seems coherent, and 89% of the participants suggested improvements points. All the participants suggested some improvements related to the description of the steps.

[1]To access both questionnaires, follow the link https://bit.ly/3Nj2tSi

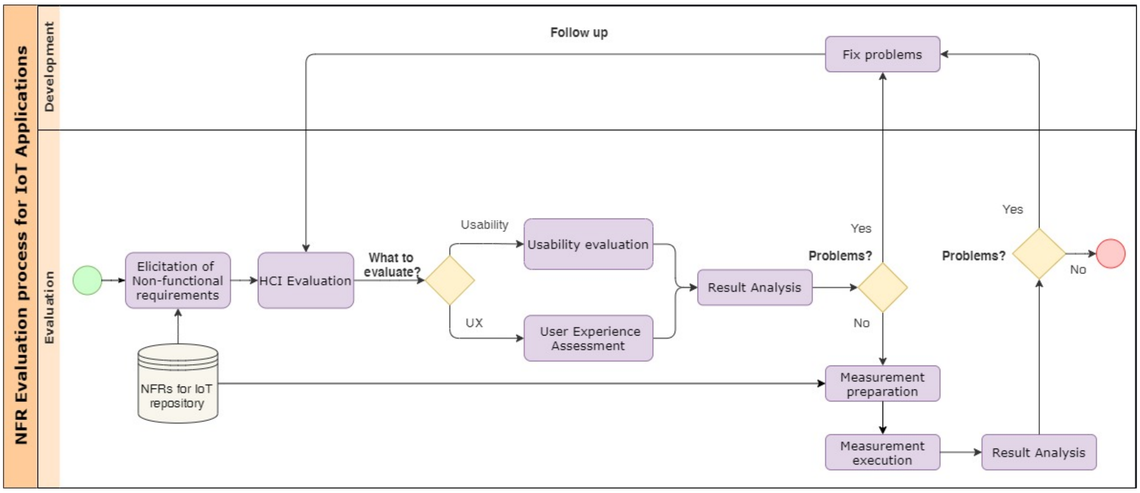

Figure 2. Initial version of the process

Regarding the coverage of IoT singularities, 56% of the participants answered that the process could cover these aspects. For 44% of the participants, the process steps would not cover all the specificities inherent in IoT applications. Also, 89% of the participants were interested in following the process, and 11% answered that they had some doubts about using this process to evaluate an IoT application.

In the second stage, after analyzing the results, according to the experts' feedback, we developed the second version of this process. The main changes in the second version were:

- The definition of who will execute each activity in the process;
- The insertion of the DECIDE framework [Preece et al. 2013] to guide the qualitative evaluation planning;
- The elimination of the division between UX and usability evaluation as they are not mutually exclusive and can occur simultaneously;
- The insertion of the method GQM [Basili et al. 1994] into the measurement planning stage;

To get feedback about the improvements made, ten experts in the IoT field evaluated this second version of the process. There were three PhDs, five doctoral students, one master's student, and one undergraduate student.

They replied to a questionnaire covering the following topics:

- Description and order of steps;
- Specificity coverage of IoT applications;
- Points that would make them use the process;
- Points that would make them not use the process.

About the steps' description, 70% of the respondents judged that the steps and activities were well detailed and 30% of the participants pointed out suggestions for improvement regarding this aspect. The suggestions were to better detail how to use the DECIDE and GQM methods, improve the description of decision-making better to correct problems detected after the qualitative and quantitative analyses, and explain the Problems-solving panel's activities types of problems to be solved in these steps.

Concerning the order of the steps, 70% of the respondents thought that the order is coherent, and 30% pointed out some improvement suggestions for this aspect. The suggested improvements were to make the activity of re-evaluating the system optional after and contemplate the possibility that there are no problems to be corrected after the analysis.

Regarding the question about the process covering IoT application specificities, all respondents believe that the process is meeting its objective because it inserts a list of NFRs specific to IoT applications and indicates the use of qualitative analysis methods specific to this type of system.

When asked about process aspects that contribute to its choice when evaluating an IoT application, the experts answered that the focus on IoT applications and the quality of interaction, systematization, and simplicity for executing the steps involved would be factors that would cause them to use the process. On the other hand, the respondents also reported some aspects for which the experts would not use the process to evaluate IoT applications' quality.

The factors reported were:

- The complexity of executing the process in its entirety and the time required to complete all the activities;
- Concerns related to finding qualified professionals to perform the evaluations;
- Insecurity in choosing evaluation techniques and software quality measures on their own.

In the third stage, after the evaluation, we take into account the feedback provided by the IoT experts, and we developed a preliminary version of the NFR evaluation process for IoT applications, presented in details in the next section.

5. NFRs Evaluation Process for IoT applications

This section presents the preliminary version of the NFR Evaluation Process for IoT applications. This process aims to guide evaluators with or without experience evaluating an IoT application. The evaluators can use this process during the system development cycle or after implementation.

This process is suitable for IoT applications since it includes a repository of NFRs and software quality measures that meet IoT applications specificities and suggests specific techniques and tools to evaluate the application qualitatively. Figure 3 summarizes the preliminary version of the process and its activities flow.

Step 1 - The first step is to select the non-functional requirements that the evaluators will observe during the evaluation. The evaluators will verify the Maximum4IoT Repository,[2], where they can find a list of non-functional requirements for IoT applications. For this phase, it is essential to involve the stakeholders to ensure that the evaluation covers all the critical aspects of the system.

If you intend to evaluate the application in both qualitative and quantitative ways, we advise you to do the qualitative evaluation before starting the software measurement

[2]Maximum4IoT Repository: http://bit.ly/NFRs4IoT-repository

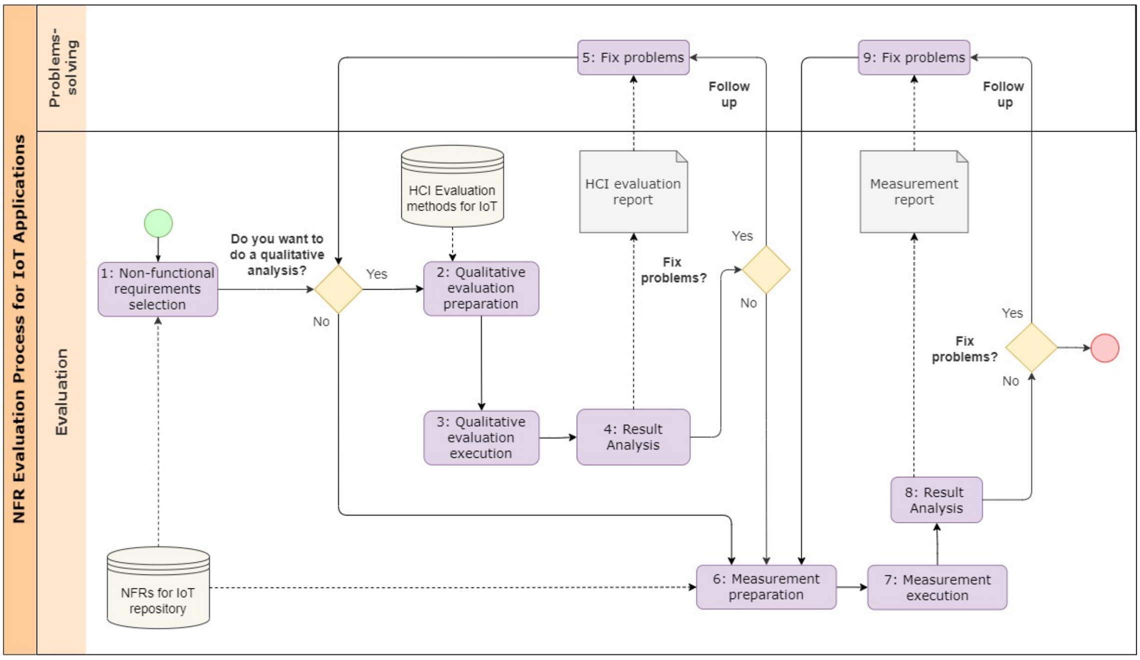

Figure 3. NFRs evaluation process for IoT applications

process. So, you will be able to identify and solve system interaction problems before planning the software measurement. If it is not possible or needed to perform a qualitative evaluation, you can skip to Step 6 - Software Measurement Preparation.

Step 2 - Before starting the qualitative evaluation, it is necessary to plan it, clarify its objectives, and answer what questions will be answered. One way to guide the planning of an evaluation is through the DECIDE framework.

- Determine the overall objectives of the evaluation;
- Explore the specific questions to be answered;
- Choose the tools and techniques to be used in the evaluation;
- Identify practical issues that need to be considered, such as the environment,
- the professionals who will conduct the evaluation, whether the evaluation will involve users, and if so what the user profile, among others details;
- Decide how to deal with ethical issues, and finally;
- Decide how the data obtained will be evaluated and reported.

It will help if you consider tools or techniques with a focus on IoT applications to cover its singularities [Almeida et al. 2020, Rocha et al. 2017, de Souza et al. 2019, Wittstock et al. 2012].

Step 3 - The evaluator perform the qualitative evaluation according to the decisions taken on Step 2.

Step 4 - The evaluator analyzes the qualitative evaluation results and report the results.

Step 5 -If the project context allows, there is a step to fix the problems reported during the qualitative assessment. As in step 1, it is up to the evaluator to decide whether to conduct a new qualitative evaluation before starting the quantitative evaluation.

Step 6 - In this step, the evaluator must define a measurement plan to determine the activities, environment, conditions, methods, measures, and instruments required to perform the software measurement. To assist in defining the objectives and choosing or defining new measures, we suggest using the Goal Question Metric (GQM) approach, which identifies the stakeholders' general objectives regarding the software quality product. We present the template suggested by GQM method to define the evaluation goals as follows:

Table 1. GQM template for defining the evaluation's goal [Basili et al. 1994]

Analyze	the name of activity or attribute
for the purpose of	overall goal
with respect to	the aspect to be considered (In our case, the NFRs selected on Step 1)
from the viewpoint of	interested people
in the context of	environment

Next, questions related to the established objective are generated and analyzed to identify which measures can be considered in the evaluation or create new measures based on the evaluation goals. Finally, if new measures are created, they need to be detailed according to a structure that allows the evaluator to apply and interpret them correctly.

Step 7 -The measures defined in Step 1 are applied according to the measurement plan;

Step 8 - In this step, the results of the quantitative evaluation are analyzed and reported to the stakeholders;

Step 9 - If the project context allows, the development team can fix the reported problems. Once the problems are fixed, a new quantitative evaluation is performed to see if the changes have positively or negatively impacted the measures. Once it is decided not to continue fixing the reported problems or if the developers have fixed all the problems, the process ends.

If followed in its entirety, this process returns to the evaluators two deliverables: a report for the system quantitative evaluation and also a report for the system qualitative evaluation.

6. Conclusions

This paper presented a preliminary version of a process for evaluating NFRs in IoT applications. Using this process makes it possible to evaluate the IoT application qualitative and quantitatively. This process uses a repository with NFRs and software measures for IoT applications and suggests HCI techniques and tools suitable to perform the qualitative evaluation. So, we intend to ensure that the evaluation process covers the specificities inherent to IoT applications.

During the construction of this process, we carried out two evaluations with IoT experts what make it possible to collect feedback on the process and suggestions for improvements, contributing to the process evolution. There is a need for further work to evaluate its effectiveness, such as an IoT application evaluation. However, we believe that the proposed process can help the software engineers by guiding them in evaluating the quality of IoT applications and capturing both objective and subjective data about the evaluated systems.

Regarding the next steps of this work, we intend to apply the proposed process to evaluate an IoT application. By applying the process, it will be possible to verify if it can cover the singularities of IoT and observe both the process complexity and the time required to execute it.

We also intend to search in the literature for more methods and techniques that can be used to evaluate NFRs for IoT applications in a qualitative way and more software measures for the quantitative evaluation.

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