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RS4AAL: A Process for Specifying and Analyzing Non-Functional Requirements in Ambient Assisted Living Systems

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Abstract

Context: The increasing life expectancy of the world's population is a reality, and combined with sharply declining birth rates, these advances in life expectancy could lead to a rapidly aging population around the world. Technologies such as Ambient Assisted Living (AAL) can provide services that enable older people to live independently, safely and healthily. During system development, it is important to ensure good specification of Non-Functional Requirements (NFR). These are requirements that define how the system will behave in certain situations and may impact the end goal of the software if not considered during the analysis and development of the project. Aims: To meet and identify all the needs and functions provided to the users of the system, this article provides a process for specifying and analyzing nonfunctional requirements in Ambient Assisted Living, called RS4AAL, which helps the requirements engineer to specify and analyze the important requirements in the development of this system by capturing the requirements with techniques such as storytelling, reuse, and legal requirements. Results: Based on systematic mapping, key nonfunctional requirements for the Health and Care in Life subdomain were identified, as well as some legal requirements that may impact system development. Conclusions: A key finding is that the personal context of older people, legal requirements such as ISO/PRF TS 823042, and AAL Guidelines for Ethics, Data Privacy and Security directly affect the specification of non-functional requirements and the design of systems. The RS4AAL helps with this mapping by showing the requirements engineer what to consider when designing AAL systems.

Keywords: Specifying and Analyzing; Non-Functional Requirements; Ambient Assisted Living; NFR Framework; Collaborative Web Tool.

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1. Introduction

The world's population is aging rapidly In a report on the aging of the world's population, the United Nations Department of Economic and Social Affairs (UN) estimates that over the next three decades, the number of people (65 years or older) worldwide will reach 1.5 billion by 2050 [1]. According to projections by the Brazilian Institute of Geography and Statistics - IBGE [2], an estimated 17% of the Brazilian population will be older people as of 2040. From the perspective of technologies aimed at this target group, the concept of Ambient Assisted Living (AAL) has been defined as products and services aimed at creating smart environments for the benefit of this group of people and improving their quality of life, especially for people with chronic diseases and disabilities [3]. Many software systems have already been developed for the older people. However, it is important to note that from the perspective of any system, issues related to modeling and evaluation of quality attributes, legal standards, and personal context must be considered and respected by all parties involved in the development.

From the perspective of older people, technology can be used to automate their daily tasks, contribute to social contact with others, and promote the learning of new knowledge. It is important that an AAL project consider the different perspectives involved in the solution, i.e., end users (patients, their families, and caregivers), clinicians, and developers (requirements and systems engineers) [4]. From a software perspective, quality attributes or Non-Functional Requirements (NFR) are constraints on the functions and services provided by the system. These can be time, development, process, and standard constraints that apply to the system as a whole [5]. In AAL, NFRs play an important role in solutions for older people because it is the combination of these attributes with the features that make the system attractive, safe, powerful, user-friendly, and easy to learn, all important aspects for older people.

Among NFRs, there are interdependencies where the correct fulfillment of one requirement directly affects the fulfillment of another; conflicts that need to be understood in order to be resolved. Some work shows the impact of NFRs on system development, but in Sittig and colleagues [6] presents challenges in health information technology related to NFR: (1) developing models, methods, and tools that enable risk assessment (NFR: traceability, reliability); (2) developing standard features and functions for user interface design (NFR: usability, satisfaction); and (3) ensuring software security in a network-enabled, networked clinical environment (NFR: security, privacy). It is not an easy task to specify and analyze an NFR that takes into account attributes such as legal requirements and the personal context of the older people. Therefore, our article presents a process to guide the requirements engineer in capturing, specifying, and analyzing NFRs in AAL. It is applied to a case study in the subdomain health and care in life, in order to provide an overview of which requirements are most important, which legal requirements should be implemented, and how they affect the system.

The following sections of the article are organized as follows: The section 2 provides the conceptual basis for the development of the paper: Process, Ambient Assisted Living and Storytelling; section 3 introduces the related works and the main differences between them; section 4 presents the process for specifying and analyzing non-functional requirements in Ambient Assisted Living; section 5 presents a web tool that supports the proposed process; and finally, section 7 concludes the article and presents suggestions for future work.

2. Theoretical Foundation

This section introduces important concepts from this article, such as: Process, Ambient Assisted Living, Health and Care in Life, and Storytelling.

2.1. Process

The growing demand for new solutions in the context of AAL requires the development of solutions with a fast and competitive way. One way to meet the production and quality requirements demanded in this context, among other resources, is the use of process. Processes are a set of activities whose goal is to transform inputs (inputs), adding value through procedures, into goods or services (outputs) that must serve customers [7], in our case the customers are the requirements engineer. According to Carvalho [8], processes consist of one or more activities that are controlled by business rules, are triggered by external or internal events in the organization, and end by some kind of event that indicates the achievement of the goal. We will use these definitions to create the RS4AAL.

2.2. Ambient Assisted Living

The concept AAL refers to a range of products, services and systems that aim to support the quality of life and independence of older person and those in need of care [9]. For Almeida [10], AAL is a critical system, and one of the success factors for these systems is good modeling of NFR [11]. A classification of AAL systems was proposed in the BRAID project [12], which defines them as four life configurations:

- Independent living: assists with activities of daily living, with activities related to monitoring life status and medical reminders. It also provides support for people with reduced mobility, such as people who use a crutch, cane, walker and wheelchair;
- Health and Care in Life: Contributes to health-related activities, such as: assistance with physical exercise, remote health monitoring and emergency assistance;
- Occupation in Life: this configuration supports the older people in the continuity of their life and professional activities;
- Recreation in Life: Allow to contribute to the performance and participation of the older people in leisure, cultural and social activities.

Afsarmanesh [13] in his work defines some desired facets that to understand concepts important to development of AAL systems:

- Information-based services, collaborating with older people health care and the relationship of other stakeholders;
- Technology based on a set of sensors that recognize the personal context of the older people with health support;
- Use of advanced devices, instruments and tools to support follow-up interventions and healthcare delivery;

- Healthcare technology support and consumer-facing regulatory infrastructure to support data privacy and standards;
- Influencing appropriately designed home and support system designs, based on the elder's contextual, cognitive, and emotional state, that adapt as they age;

2.3. Storytelling

Storytelling as a technique has been used for knowledge management [14] and software requirements elicitation [14, 15]. Studies in psychology have found that people learn best from stories [16]. In Rinzler [17] points out that listening to a story makes the listener experience everything he hears as if he were part of the whole plot. The listener can empathize with each event and fill in any details that may have been left out. Furthermore, listeners are able to evaluate and remember each piece of information because it is part of a logical and realistic whole that validates itself with their own experience. Obviously, telling a person's experience and needs in the form of a story is more relaxing and flexible than using standard, ready-made questions to gather requirements. By exploring many useful ways of representing requirements for engineers, existing structured analysis and modern methods have become too abstract and distanced themselves from how people normally learn and communicate. Storytelling is a logical process that everyone understands intuitively. Telling a story about what the system does with an understandable narrative is more engaging and leads directly to an improvement in the process of gathering information and structuring requirements [17].

To better understand this proposal, the next section presents the main works related to this research and the main differences between them.

3. Related Works

The NFR Framework was proposed by Mylopoulos, Chung, and Nixon [18] and was implemented by Chung and colleagues [19] with emphasis on NFR modeling and analysis. The NFR Framework is intended for general use, but for use in AAL it's possible to add extensions for use in AAL: (i) a requirements elicitation step where the context of use (use scenarios based on your routine) and user preferences can be captured; (ii) in the "identify specific NFRs" step, support for other artifacts such as legal requirements, taxonomies or ontologies; (iii) how to specify the representation of scenarios (soft-goals and operations) of the SIG tree that can be affected by the context of use and user preferences. (iv) How the catalog can be supported to enable reuse of other artifacts, e.g..: Storytelling, legal requirements, hardware specifications, and development platforms.

Numerous research papers have been published addressing the state of the art of domain AAL and NFR modeling for AAL. The authors in Calvaresi and colleagues [4], for example, present a goal-oriented requirements engineering approach (GORE) for mapping needs and requirements to the domain AAL, focusing on defining an architecture for a home care system.

In Amina el al. [20], the authors focus on the study of AAL system requirements and implementation challenges, and definitions, requirements, and specifications of reference models and reference architectures in AAL. In all these works, no process could be found to support the requirements engineer in capturing and

modeling system requirements for AAL.

4. Specifying and Analyzing Non-Functional Requirements in Ambient Assisted Living

The Figure 1 presents the overview of RS4AAL: Requirements Specification for Ambient Assisted Living [21] with two layers: RS4AAL and NFR Framework. The RS4AAL layer consists of two subprocesses (Elicit Requirements with Storytelling and SIG Tree View), one process (Associate User Preferences), and the AAL repository. RS4AAL starts with the initial requirements elicitation with storytelling; it is a sub-process with steps for eliciting non-functional requirements and personal context [22].

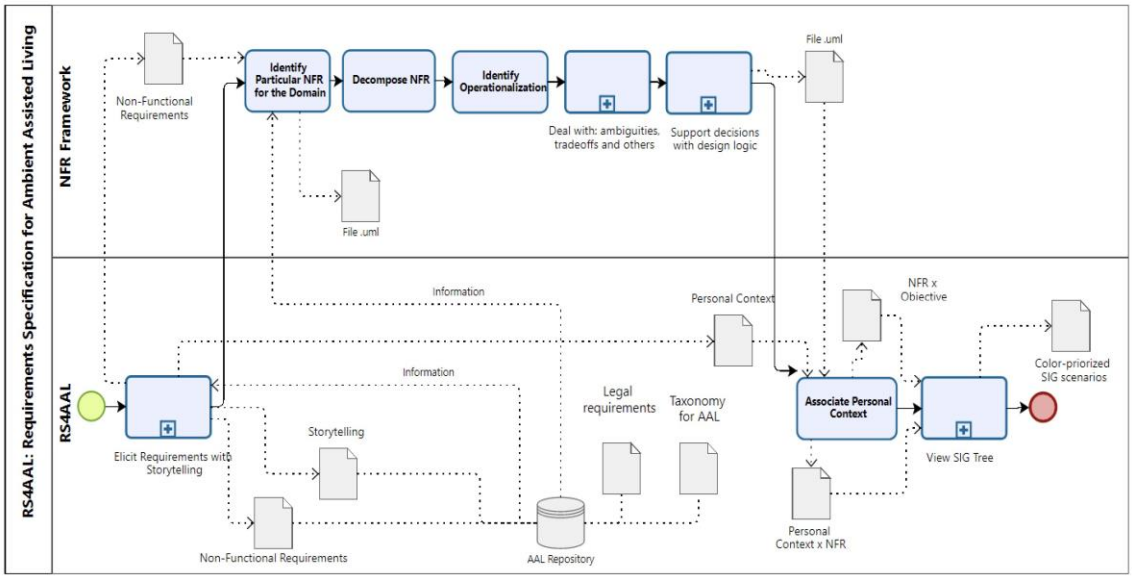

Figure 1: Overview of the RS4ALL Process.

The results of this sub-process are the artifacts: NFR, storytelling, and personal context. These artifacts are used as input for other steps. The ”Associate Context of Use” process examines the influence of the context and preferences of the older people on the requirements so that the SIG tree can be dynamically designed according to the needs of the older people. The sub-process ”Visualize SIG Tree” aims to create SIG scenarios with colorful visualization so that the requirements engineer and the developer can visually understand that the system is dynamic according to the context of use of the older people. Finally, there is the AAL repository, a database that stores SIG trees and other artifacts that contribute to development with reuse, such as storytelling, NFR, contexts of use, taxonomies, and legal requirements. All items added to the repository are classified by life setting, category, and subcategory of AAL, which facilitates the reuse of these items for the domain (vertical and horizontal reuse) [23].

In the NFR Framework Layer, Chung [19] lists several steps (”Acquire or Access Knowledge”, ”Identify Particular NFR for the Domain”, ”Decompose NFR”, ”Identify Operations”, ”Dealing with: ambiguities, trendoffs and others”, ”Support decisions with design logic”) of your process that are not necessarily sequential and may need to be iterated several times during the design process. RS4AAL updates Chung’s proposed

process by replacing the ”Acquire or Access Knowledge” process with ”Elicit Requirements with Storytelling” and started the ”Identify Particular NFR for the Domain” process to obtain more information generated from the AAL repository that contains information needed for an initial project setup, as explained in the next sections

4.1. Elicit Requirements with Storytelling

In this subprocess, the narrative [15] is used to capture the functional requirements, NFR, context of use, and cultural aspects of older people, important information for proper understanding of the system being developed. Once captured, RS4AAL has a database that relates this information and proposes new artifacts with their respective relationships. In this work, the artifacts generated by RS4AAL are: functional requirements, NFR, context of use, legal requirements, taxonomy, domain and AAL subdomain.

Each of the identified artifacts plays an important role in the following processes. For example, the functional requirements are the input for the developer to identify the programming language, database, and architecture that can be used in the project. The NFRs are the input to the ”identify particular NFR for the domain” process, which must suggest to the requirements engineer with access to the repository AAL other artifacts related to the system, such as specific legal requirements for life settings. To support the identification of NFRs from storytelling, RS4AAL has a database of these artifacts and defines steps to capture them manually or by using machine learning techniques [24, 25] to classify NFRs.

4.2. Identify Particular NFR for the Domain

In the systematic mapping of Garces and colleagues [26], a taxonomy for AAL systems was presented, based on ISO /IEC 25010. In the mapping of Junior and colleagues [27], this taxonomy was updated with new requirements, as can be seen in Figure 2.

Based on this work, it was possible to identify the most relevant NFRs for each AAL life setting and category. Since the previous step also captured the subdomain AAL, in addition to the taxonomy, RS4ALL will propose the legal requirements that will help identify new requirements, e.g., the legal requirement ”AAL Guidelines for Ethics, Data Privacy and Security” [28] is intended for all researchers, developers, primary and secondary end users in the domain AAL. This document provides considerations on how to create ethical excellence for solutions aimed at active and healthy aging through digital technologies.

As part of RS4AAL, this document was mapped to and related to the NFR, resulting in the creation of SIG trees.

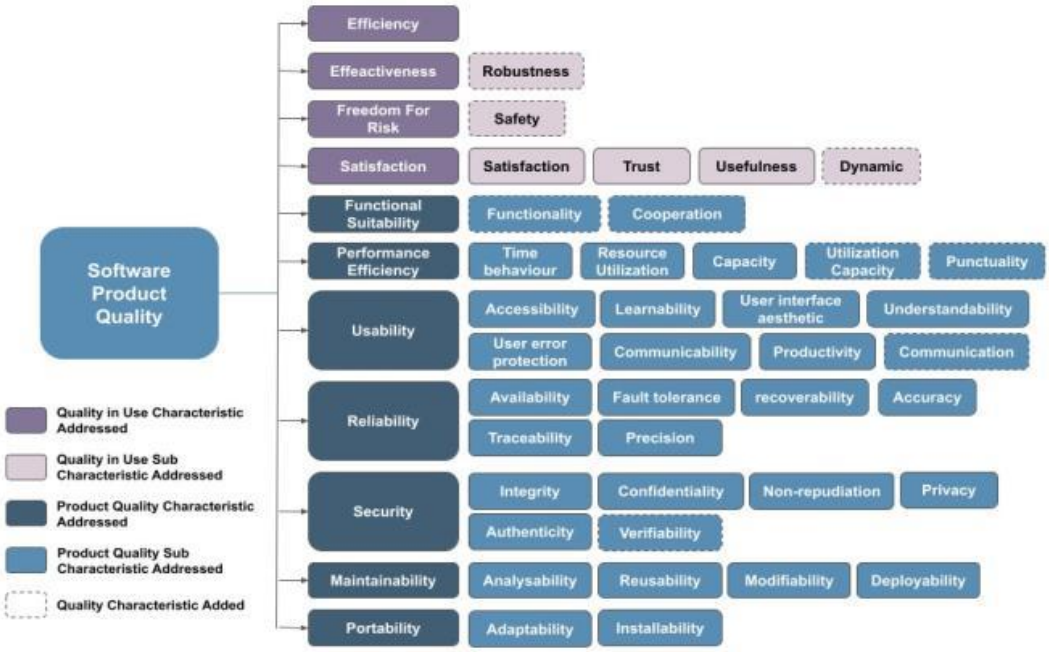

Figure 2: Overview of the NFR grouping analysis from ISO/IEC 25010.

4.3. Associate Personal Context

Each older person has different preferences and contexts, which may depend on the community in which they live, their region, and the time it takes them to get used to their routine [22]. Here we use an approach in which a set of pairs is formed for each NFR and assigned a weight w (a real number in the interval [0,1]) [29]. Each pair indicates the prioritization (w) of the NFR. A value of 0 represents minimum relevance, while a value of 1 represents maximum relevance. It is important to note that the weighting for each NFR should be mutually exclusive.

4.4. View SIG Tree

This process explores how user preferences across NFRs can be represented in a SIG tree. Based on the process described above, the RS4AAL has the weights that each NFR can have based on personal preferences. Since the preferences of older people can change depending on their needs, a set of SIG's is created to provide guidance to the requirements engineer on the possible scenarios that the SIG tree can take. To create these scenarios, the visual representation method of color-based prioritization described by Pimentel [30] be used, which aims to minimize the cognitive effort required for prioritization analysis. Basically, each goal is given a color-coded label to visually indicate that this goal may have minimum, medium, or maximum importance in this particular scenario, depending on the weighting determined in the previous process.

In the Figure 3, you can see that for this scenario, measuring the positioning of older people has the most importance (red color), Wi-Fi has medium importance (yellow color), and BLE or RFI has minimal importance (gray color). The tool helps the requirements engineer adjust the colors as needed.

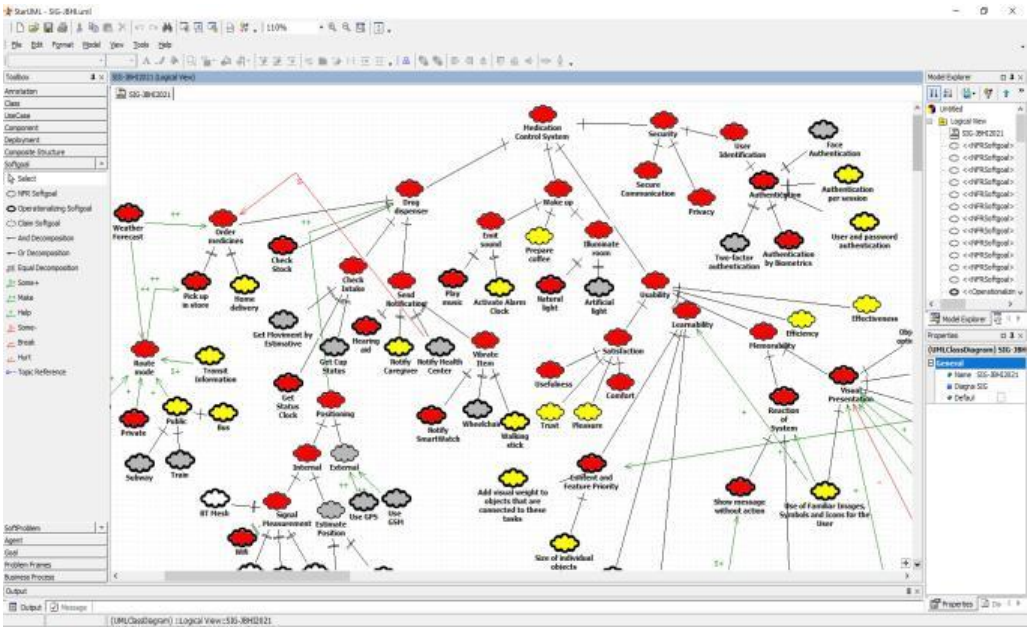

Figure 3: Color-based SIG Tree View.

To facilitate the use of this process, the next section presents a web tool that supports the requirements engineer at each stage of development.

5. RS4AAL Tool

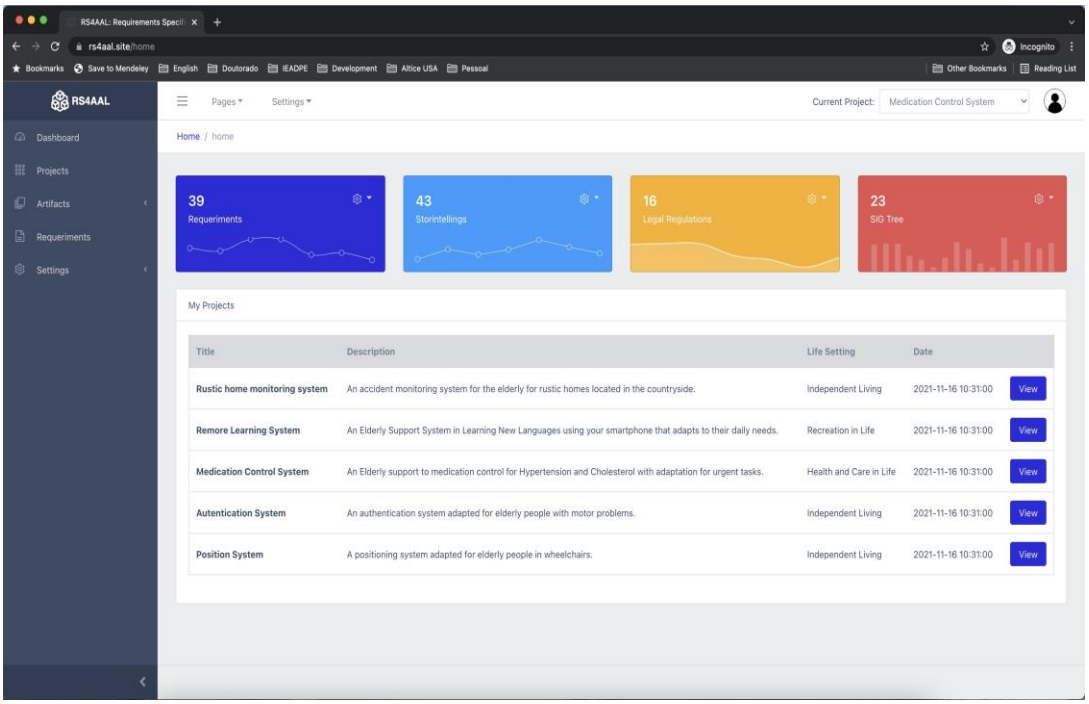

Figure 4: Main Screen of the RS4AAL Tool

To support the implementation of the RS4AAL process, a collaborative web tool [31] was developed to support

the requirements engineer in all phases of the process. In Figure 4, the information available in the repository (requirements, models, storytelling) is presented on the initial page. The tool was developed using PHP programming language and MySQL database and runs on AWS infrastructure. The tool also has a REST service online [32] to facilitate integration with other tools that want to access the artifacts. This access is possible via a token generated when the tool is registered.

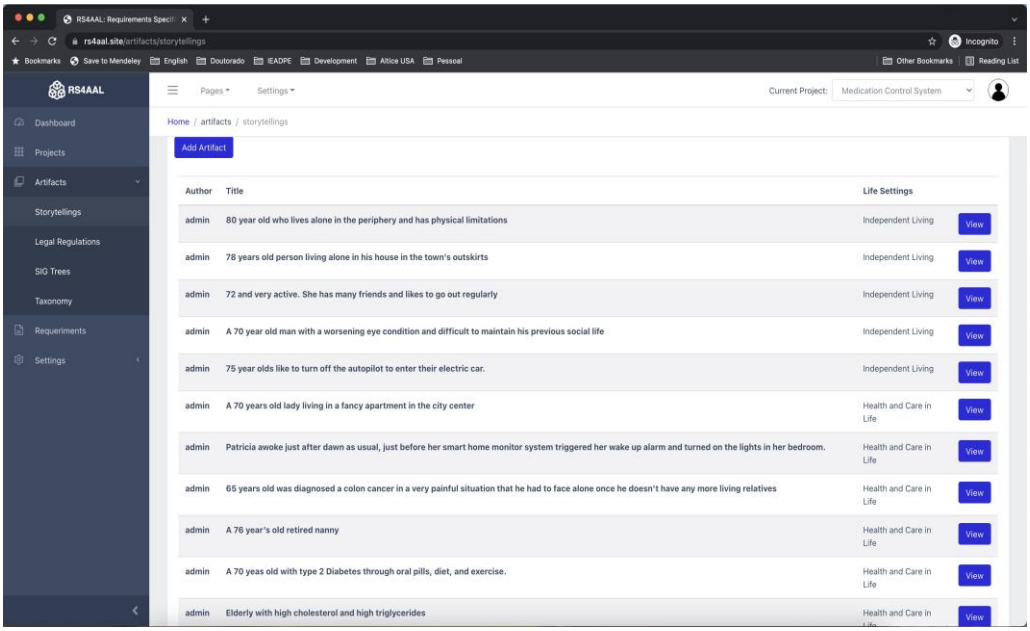

Figure 5: List of Artifacts of the RS4AAL Tool.

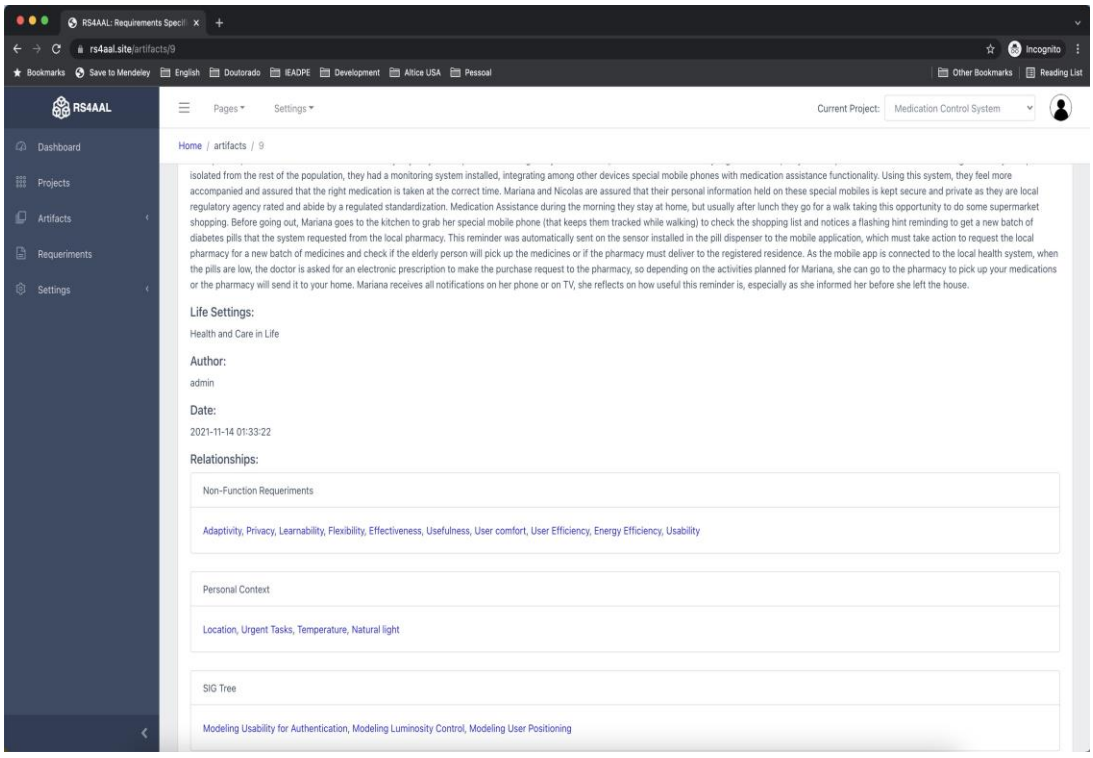

Figure 6: Show Artifacts with their Relations.

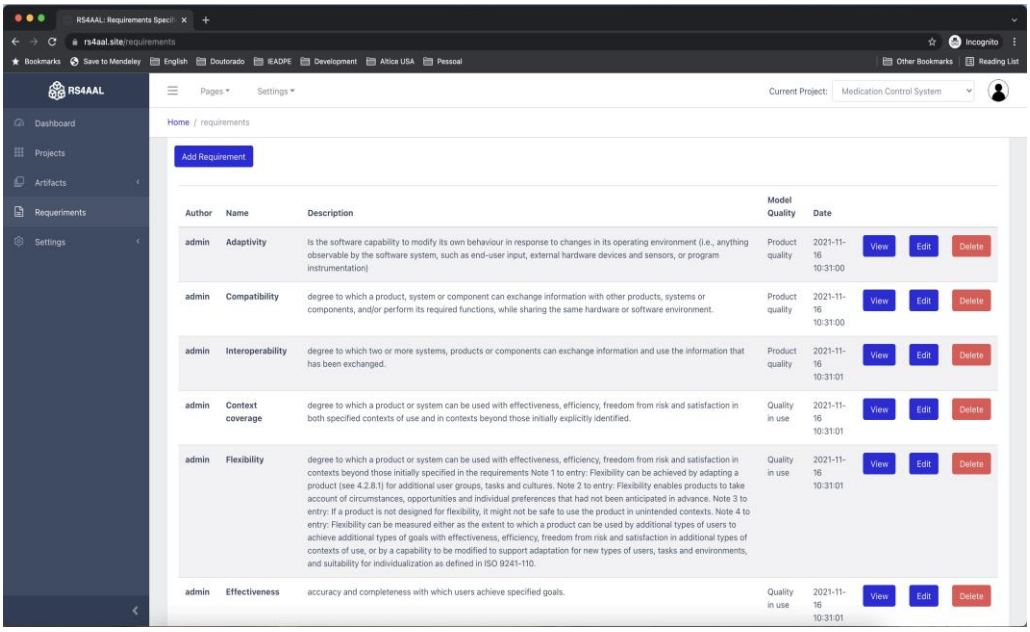

Figure 7: List of Non-Functional Requirements of the RS4AAL Tool.

In Figure 5 you can check a storytelling list with the respective life settings. Looking at the details, you can see the functional requirements, NFR, and personal context (Figure 6). Figure 7 displays the list of non-functional requirements available in the tool. For each NFR, the following information can be retrieved: Description, Quality Model (product or use), Characteristics or sub-characteristics, Origin, and to which life settings the NFR applies (this information can also be viewed under the Taxonomy menu item).

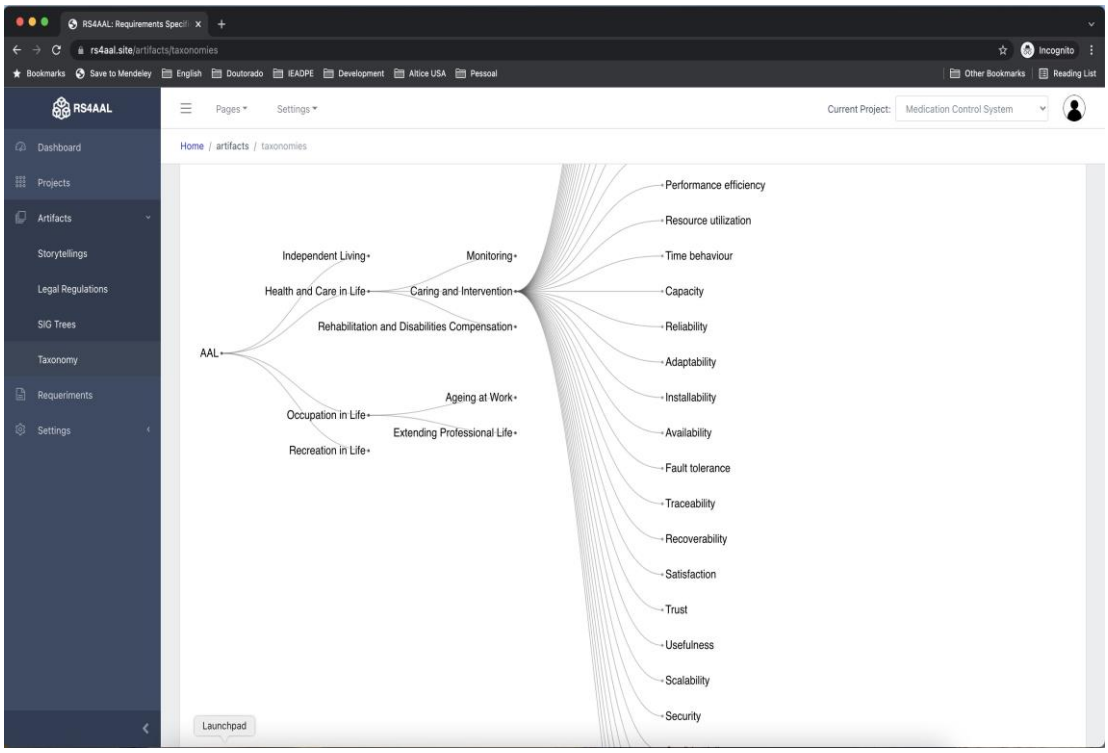

Figure 8: AAL Taxonomy Tree.

The Figure 8 presents the AAL taxonomy, with a list of life settings and their respective NFR. The RS4AAL tools present a set of NFRs to consider for the project. In addition to the taxonomy, the tool also includes a set of legal requirements that relate to the AAL life settings. Each legal requirement is linked to an NFR and in some cases to generic sections of the SIG tree.

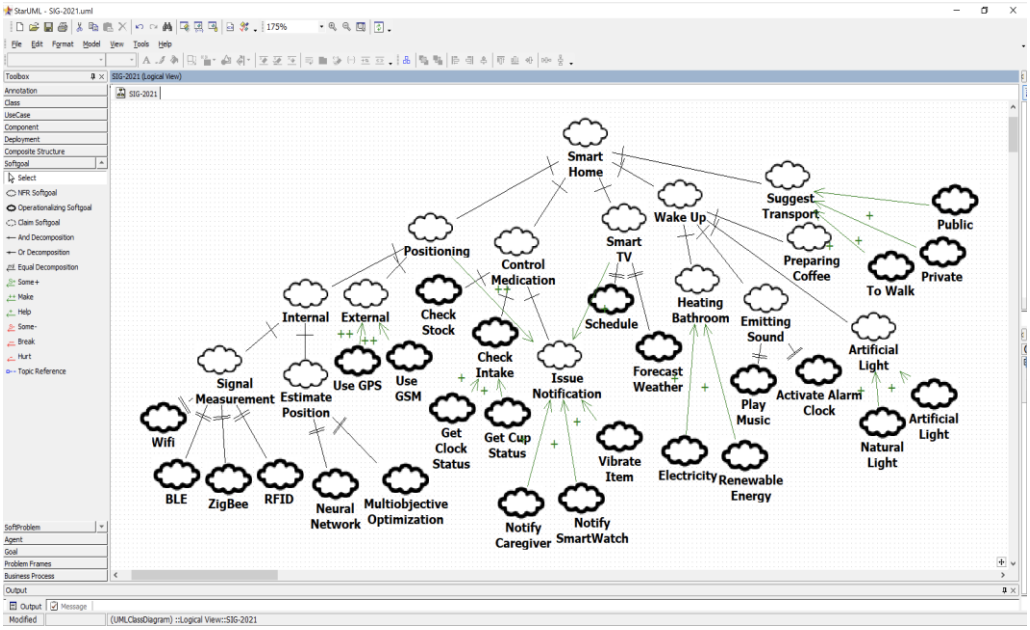

Figure 9: Modeling SIG Tree with StarUML.

As a result of this process, a file XML with extension .uml is generated containing the SIG tree with the NFR identified in the previous steps, which is imported into the StarUML tool version 5.0.2.1570 that supports modeling of the SIG tree, as shown in Figure 9.

5.1. AAL Repository

The RS4AAL process has a repository that contains the NFR framework catalogs and other artifacts that support the requirements engineer in creating systems AAL. Each artifact is registered in the repository and associated with information: life settings, source, registration date, update date, and their relationships. The repository has a database and a service layer REST [32], making it technology independent. To understand the use of RS4AAL and the tool, the next section presents a case study in the area of Health and Care in Life that helps an older person manage his medications.

6. Medication Assistance System for Olderly

There are several theories that can explain the problem of successful aging. One of them is the activity theory [33], which assumes that older people participate actively in society, that they do not withdraw from their professional tasks, family and social network, which prevents the deterioration of their cognitive abilities and

thus promotes physical and mental health and adaptation to social integration regardless of their limitations.

Active aging [34] depends on a variety of factors. Disease prevention, which includes the treatment of diseases that are particularly prevalent in older people, should be a priority.

Based on this problem faced by the older people, a mobile medication assistance app called MedicationForYou [35] was developed to help the older people control, manage, and inventory their diabetes medications. The app also connects to various devices in the home, such as the medication box, blood glucose meters, sensors, and weather forecasts to help with outdoor activities. By registering basic information in the RS4AAL tool, such as project name (Medication Control System), description, and life settings, the requirements engineer has access to a list of artifacts that can be reused. The [36] shows an excerpt of the storytelling that the tool suggests based on the reported properties.

The Figure 6 presents the other artifacts associated with this storytelling, such as the non-functional requirements (privacy, learnability, flexibility, effectiveness, usefulness, user comfort, user efficiency, energy efficiency, usability), the personal contexts (location, urgent tasks, temperature, natural light), and SIG trees (modeling usability for authentication, modeling brightness control, modeling user positioning).

Following this process, the requirements engineer reused the artifacts from this first step and moved to the next step, ”Identify Particular NFR for the Domain” based on the Recreation in Life setting. The RS4AAL tool repository contained the following artifacts:

Based on AAL Taxonomy:

- NFR important to this life setting: satisfaction, learnability, privacy, and usability;

Based on Legal Requirements:

- International Standards ISO / TC 314 Ageing Societies: was established to develop standards that address the societal needs of the aging population and provide guidance to organizations that provide services to this age group;
- ISO / PRF TS 82304-2 Health Software: establishes quality requirements for health systems and creates a quality model for health applications to illustrate the reliability and quality of health systems;
- Ethical solutions [28]: (i) specify what people (health professionals and family members) do when an alarm is triggered; (ii) use lighter colors depending on age so they can be easily identified.

Based on the related works and their improvement points, a process specifying and analyzing Non-Functional Requirements in Ambient Assisted Living is presented in the next section.

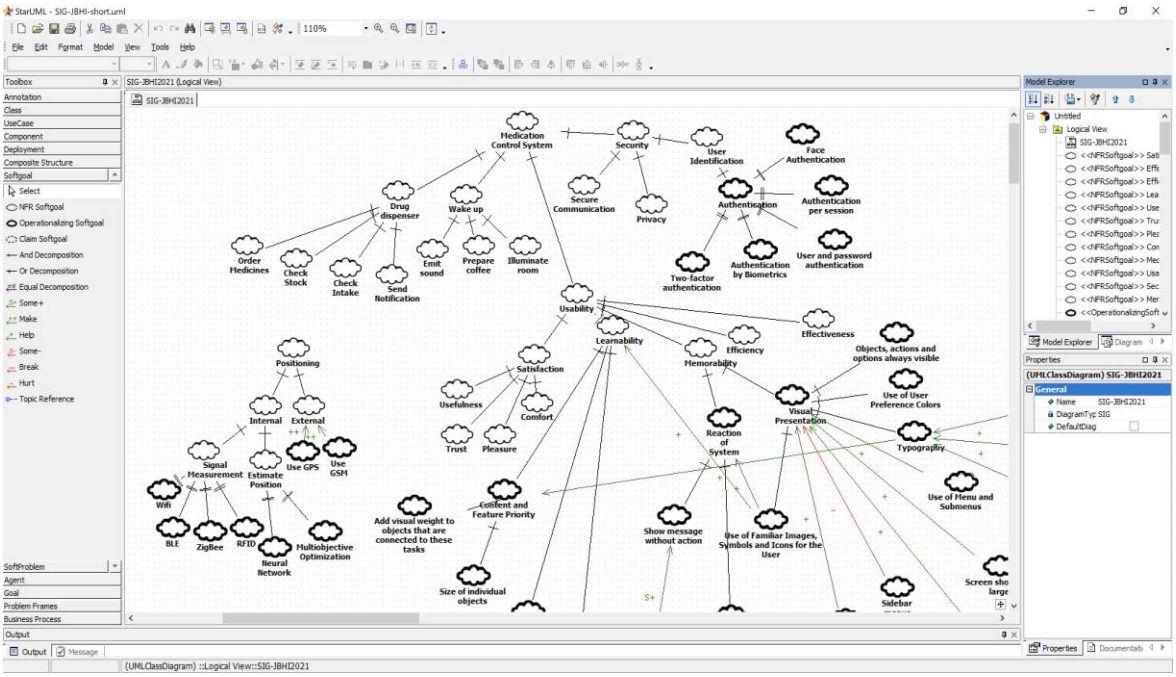

Figure 10: File generated from RS4AAL and imported into StarUML.

After you confirm the inclusion of the new artifacts in the project, the RS4AAL tool generates an .uml file containing the SIG tree with the selected information. In the Figure 10 of the StarUML tool, it is possible to identify the main SIG (Medication Control System) tree related to the project and other SIG trees related to the taxonomy and legal requirements (authentication and positioning).

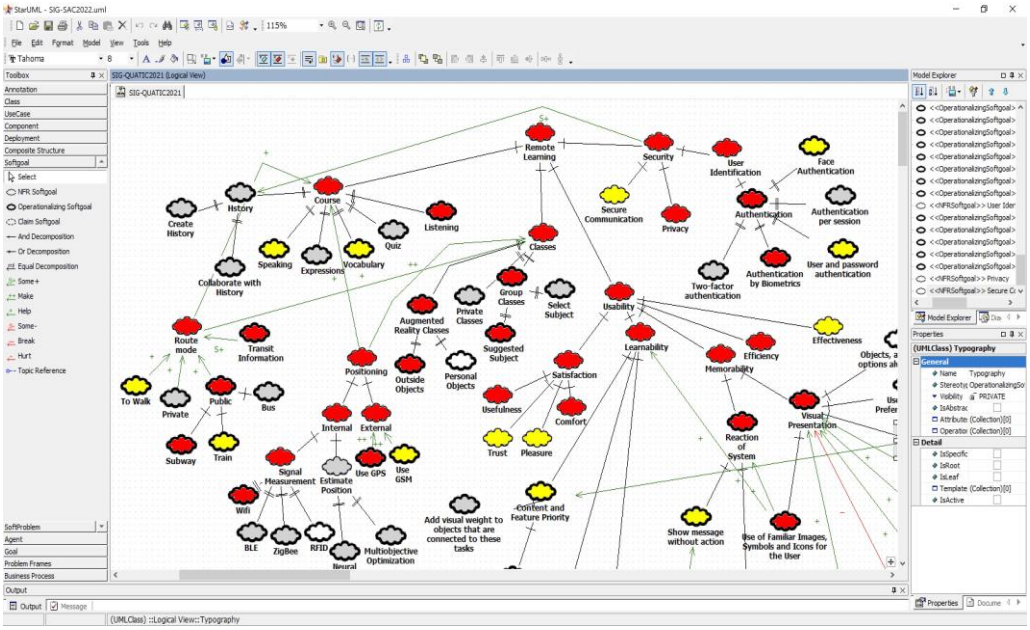

Figure 11: Part of the SIG tree of the scenario generated by the RS4AAL Tool.

In the Figure 11, a scenario is presented in which Mariana (is a fictional user) uses technology. She receives notifications about medications through her smartwatch and hearing aid. If Mariana does not accept the

notification over a period of time, a new notification is sent, this time to her caregiver.

According to the weather forecast, it's going to be a sunny week. On the day when her medication supply is running low and she needs to walk because of her diabetes, the system suggests that she pick up her medication at the pharmacy, walking part of the way and using public transportation. If the weather forecast announces a rainy week, the medication will be ordered from the pharmacy and delivered to Mariana's house, represented by the color yellow. As a form of authentication, the app suggests the use of biometrics and credentials (username and password). The website SIG shows the importance of focusing on usability and using techniques that facilitate learning and using the application.

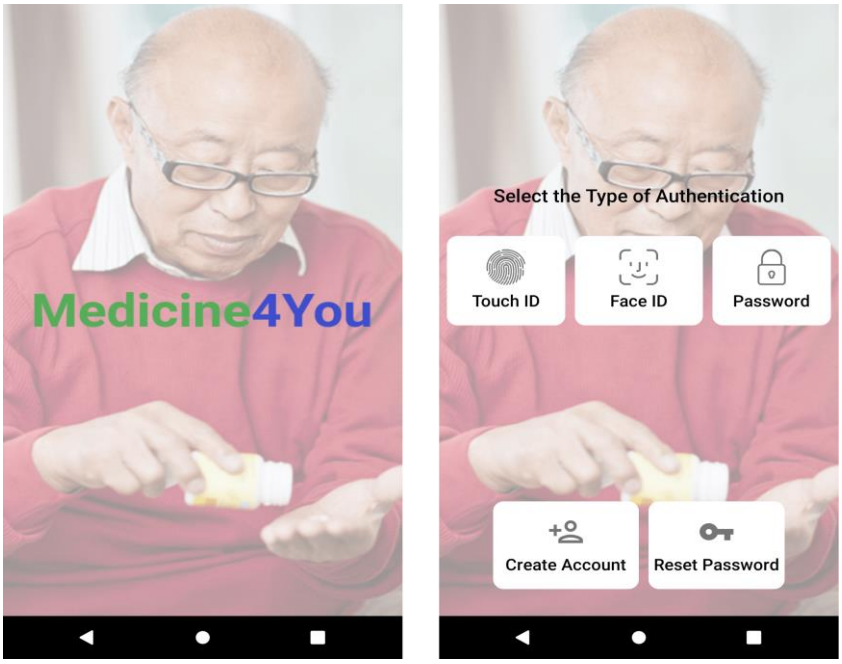

Figure 12: Mobile App Android: Splash Screen and Authentication.

Once all scenarios were validated, the development team began implementing the MedicationForYou [35] mobile app. In Figure 12, it is possible to review the app's home screen and see how the older people person can authenticate, in this case via: TouchID, FaceID or username and password. After authentication, which can be done via biometrics, FaceID, or credentials, the older people is redirected to the main screen of the mobile app, which can be seen in Figure 13. Based on the artifacts in the RS4AAL tool, the developer did not use the sidebar menus because they directly affect the user experience in mobile apps [37, 38].

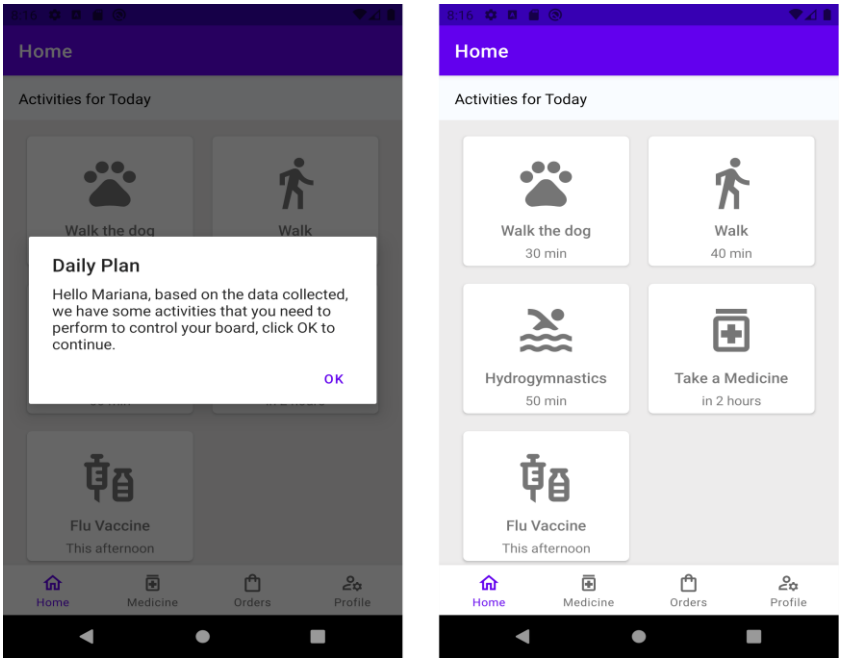

Figure 13: Mobile App Android: Home screen with activity suggestions.

When the older people access the app for the first time in the day, it displays a message with scheduled activities based on information provided by the older people and their health center. Based on the SIG scenario on Figure 11, the mobile app prioritizes activities related to diabetes management. Based on the information from the health center, the app also indicates that the older people should take their medications within two hours and go to the health center in the afternoon to get a flu shot, as seen in Figure 13.

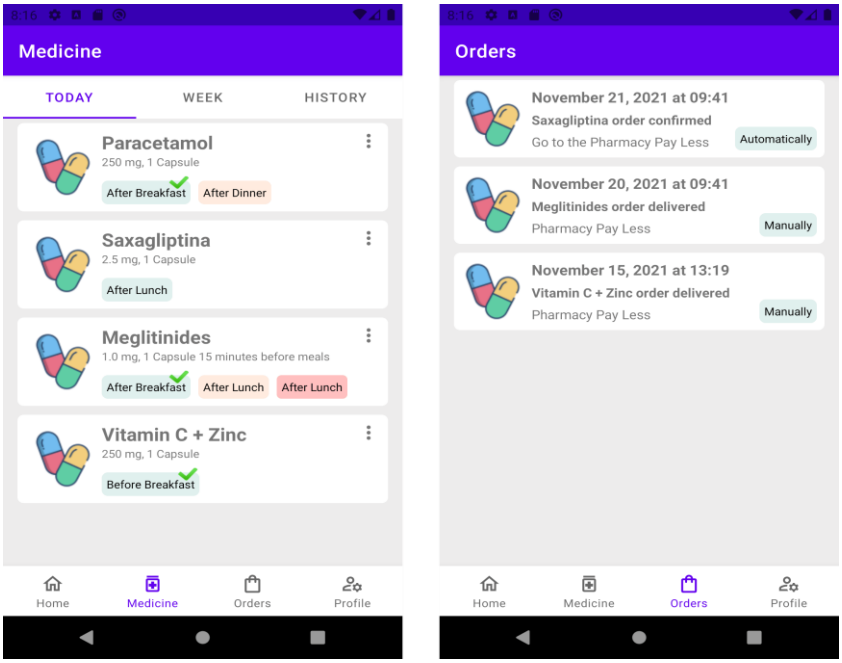

Figure 14: Mobile App Android: Class screen with the option for private or group lessons.

Using a sensor in the medication dispenser, the system knows the inventory level and automatically generates orders for the item. The image Figure 14 illustrates this functionality where 3 orders were placed. The first order was automatically generated by the system, and the caption indicates that the older people should pick up the medication at the pharmacy.

The status ”delivered” means that the pharmacy delivered the product, filled the dispenser, identified the new medication by weight, and updated the status to ”delivered.” If the dispenser does not receive the medication in a timely manner, a notification is sent to the elder’s caregiver and family to resolve this issue.

7. Conclusion and Future Work

This paper presents a process for the specification and analysis of non-functional requirements in Ambient Assisted Living Systems, supported by the RS4AAL tool. This is an environment where the requirements engineer can find guidance for specifying and analyzing requirements (functional and nonfunctional) for Ambient Assisted Living based on personal context, taxonomy, and legal requirements. The tool also supports the requirements engineer in mapping NFRs from storytelling, where this process can replace the ”acquire or access knowledge” process of the NFR framework. Another important contribution was the ”Identify Particular NFR for the Domain” process, which now receives artifacts from the AAL repository to assist the requirements engineer in discovering new requirements through taxonomy and legal requirements. The RS4AAL process proposed an extension to the SIG tree using a color structure to identify operations based on how their behavior matches the preferences and current context of the older people.

7.1. Main Contributions

The RS4AAL process presented in this article is intended to guide the requirements engineer in specifying requirements (functional and non-functional) for Ambient Assisted Living systems based on personal context, taxonomy, and legal requirements.

The following aspects are the main contributions of this study:

1. A Process to guide the requirements engineer in specifying non-functional system requirements in AAL and its subdomains;
2. A guide to consider personal context and reuse (vertical and horizontal) in specifying system requirements in AAL;
3. A guide to development based on legal requirements, taxonomy, and ontologies;
4. A guide to capturing system requirements and personal context using storytelling;
5. A SIG tree view to adapt to user preferences and current context;
6. A guide to support taxonomies and legal requirements in the process of NFR-specific identification in the NFR Framework;
7. An AAL repository to support the NFR Framework catalog and other artifacts: storytelling, legal requirements, and taxonomies.

7.2. Future Work

As future work, it can be highlighted:

1. Support for SIG tree modeling within the RS4ALL tool;
2. Evaluation of the use of the process in other life domains, such as Occupation in Life;
3. Validation of the RS4ALL tool based on usage and perceived usage in collaboration with industry;
4. Validation of other algorithms to automatically classify requirements that are not required.
5. We are working on new work that validates this approach in the development of an app to help the elderly monitor, manage, and inventory their medications. This app is in the testing phase and the results of this approach are very promising. The version of the Android app and implementation details can be found on GitHub [35].

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