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A systematic mapping on quality attributes and quality models for ambient assisted living systems.

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Abstract

Context: Population ageing is currently taking place across the globe and it is already a reality in many developed countries. In this context, Ambient Assisted Living (AAL) has become an essential, multidisciplinary research topic, aiming at providing software systems and services that assist people (especially elderly or disabled with special needs) in their everyday life activities. Considering the critical nature of AAL systems, several initiatives have already contributed to the improvement of their quality, by mainly focusing on their non-functional requirements. However, despite the importance of quality assurance in AAL systems, there is a lack of a comprehensive analysis on how quality assurance is performed in such systems. This fact might in turn lead to an absence of standardization with regard to the quality assurance process of these systems.

Objective: In this report, we provide the planning and conducting phases of a systematic mapping (SM), which aim to offer a broad, detailed panorama about the state of the art on quality models (QMs) and quality attributes (QAs) that are important for the AAL domain. In particular, we aim at identifying which QAs are the most frequently studied, how they have been identified as relevant to AAL, and how their relevance is evaluated. In parallel, we characterize the QAs for each AAL sub-domain and identify the critical QAs for AAL systems.

Method: We performed a Systematic Mapping (SM), following well established guidelines for conducting SM in the software engineering area. We used six publication databases to cover all published material pertinent for our SM. We initially obtained 287 studies that were filtered based on a set of well-defined inclusion/exclusion criteria, resulting into a set of 27 studies that were used for exploring QAs for AAL systems.

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Chapter 1

Introduction

Ambient Assisted Living (AAL) constitutes a fundamental research domain that has recently received significant attention, mainly in Europe and North America. AAL has arisen as a philosophy which includes methods, products, services, and AAL systems to support the everyday lives of disabled and elderly people, promoting mainly their independence and dignity [1].

The development of AAL systems is considered quite complex, since: (i) such systems sometimes involve different technologies, like actuators, sensors, communication technologies, and software systems of related domains (e.g., eHealth or smart homes); (ii) they must be personalizable, adaptive, and anticipatory; and (iii) they must be non-invasive (or invisible) and must be developed to fit different circumstances, e.g., use at home or at work, or through mobile support [1].

AAL systems can be considered as embedded ones, in the sense that they refer to computational systems designed to perform one or several dedicated specific functions, sometimes, as part of a complete device including hardware and mechanical parts [2]. Moreover, AAL systems are critical, due to the fact that in case of failure they may cause serious damage to human lives [3]. Furthermore, AAL systems exhibit hard constraints on critical quality attributes, such as dependability, safety, performance, and security [3]. In this perspective, the assurance of quality requirements should be considered a key concern during the development of AAL software systems. In the current literature, one can identify several initiatives, intending to improve and to some extent guarantee the quality of such systems. These initiatives have mainly discussed on quality models (QMs) and quality attributes (QAs) for those systems. However, to the best of our knowledge, there is a lack of a complete, detailed panorama on how quality is being treated in AAL systems. Additionally, the state of the art lacks reporting a consensus on which are the most relevant quality attributes, critical attributes, or quality models that could be more fitting for AAL systems. Moreover, there is an absence of a broad analysis on the strategies used to establish quality requirements of AAL systems (i.e., target quality attributes).

Motivated by the aforementioned shortcomings in the state-of-the art, the main contribution of this article is to provide a broad, detailed panorama on quality attributes that are important in the AAL domain. For this, we have applied the systematic mapping (SM) technique [4], which enables researchers to conduct a complete and fair evaluation of a topic of interest. Important points of contribution expected are: (i) the identification and analysis of approaches utilized to define, evaluate, use, and address the quality attributes/models found in the literature; (ii) the identification of the most important quality attributes for AAL systems; and (iii) the proposal of research topics that should be investigated. In parallel, we also intend to initiate a broader research area that promotes the development of quality-based AAL systems, centered mainly on the welfare of elderly and disabled people.

The remainder of this report is organized as follows. Chapter 2 presents a background on quality in software systems, focusing in quality attributes and models; this Chapter also presents a background on the AAL domain. Chapter 3 provides an overview of the related work. Chapter 4 presents the planning and conduction of our systematic mapping. Finally, Chapter 5 presents our conclusion and future work.

Chapter 2

Background

In this Chapter, we briefly present the context in which our SM is placed. To achieve this, we briefly present a background on quality assessment of software systems, including quality models (QMs) and quality attributes (QAs). Moreover, we discuss the objectives, the sub-domains, and the most important characteristics of AAL systems.

2.1 Quality of software systems

Over the years, a variety of models has been proposed aiming to support the software development, through the description, assessment, and/or prediction of software quality [5]. Such quality models allow the identifation of quality attributes that can be used so as to orient the design of software systems. Through this perspective, it is possible to find three types of quality models [6]: definition, assessment, and prediction quality models, which are detailed as follows.

Definition quality models: Models that provide taxonomies or hierarchical decompositions of quality attributes. Shortly, a quality attribute[1] is a characteristic of software which specifies the degree of an attribute that affects the required software quality [7]. Definition quality models aim at decomposing quality down to a level that allows to measure and evaluate the software quality. Important definition quality models have been established during the last decades. The quality model proposed by McCall et al. [8] is considered as the precursor of the modern quality models. McCall's model established three major perspectives for defining and identifying the quality of a software product: product revision, product transition, and product operations. Each of these perspectives describes a set of quality attributes that refers to the ability of a software

[1]Quality attribute is a generic term to quality factors, quality subfactors, or metric values [7]

system to undergo changes, to adapt to new requirements, and to adequately perform its functionalities. Similarly, the quality model established by Boehm et al. [9] attempts to qualitatively define software quality by a given set of attributes and metrics.

Moreover, the ISO (International Organisation for Standardization) and the IEC (International Electrotechnical Commission) in 1991 proposed the international standard ISO/IEC 9126 [10], and as its successor, in 2011, the set of international standards denominated ISO/IEC 25000:SQuaRE (Systems and software Quality Requirements and Evaluation) [11]. SQuaRE defines the ISO/IEC 25010 [11] and the ISO/IEC 25012 [12] standards that establish quality models for computer systems and software products, quality in use, and data. Specifically, ISO/IEC 25010 standard defines: (i) a "software product quality model" composed of eight characteristics (i.e., functional suitability, reliability, performance efficiency, usability, maintainability, security, compatibility, and portability), which are further subdivided into subcharacteristics measured internally or externally; (ii) a "system quality in use model" composed of five characteristics (i.e., satisfaction, effectiveness, freedom from risk, efficiency, and context coverage), which are further subdivided into subcharacteristics measured when a product is used in a realistic context of use.

Assessment quality models: These models evaluate quality attributes detailed in the definition quality models. Examples are the metric-based models such as the Maintainability Index (MI) [13] that organizes the software factors to determine or influence maintainability into a hierarchical structure of measurable attributes, and for each attribute it establishes a consistent metric definition. MI is comprised of weighted Halstead metrics (effort or volume), McCabe's Cyclomatic Complexity, lines of code (LOC), and number of comments [14]. Other example is Qualixo [15], a factor-criteria-metrics quality model that uses measurements to assess software quality. These measurements cover a number of specification accuracy, programming rules, and test coverage [15]. Goyal and Joshi [16] developed a model based on the QMOOD (Quality Model for Object Oriented Design) [17] to assess quality attributes of design properties of Java programs (e.g., reusability, functionality, effectiveness, understandability, extensibility, and flexibility).

Prediction quality models: These models are usually based on source code metrics or past defect detection data to estimate the number of systems defects, mean times between failures, repair times, and maintenance efforts [6]. Good examples of these models are the software-reliability growth models (SRGM), which attempt at modelling processes associated with software failures, using various assumptions related to the test procedures. Discussion of the earlier SRGM is presented by Zeephongsekul et al. [18]. One of the most recent SRGM was proposed by Ahmad [19], which established a stochastic model as a counting process to represent the number of failures experienced in a given period of time by the system.

2.2 Ambient Assisted Living

Aiming at enhancing the quality of life for everyone, the Ambient Assisted Living (AAL) domain emerged in the 1990s, and by the middle of the 2000s it has received more attention. AAL is a relatively new field and has become an increasingly important, multidisciplinary research topic for both medical and technological research communities. AAL refers to concepts, products, and services, improving autonomy/independence, comfort, safety, security, and health for everyone (with a focus on elderly people) in all stages of their life [1]. AAL is primarily concerned with the individual in his/her immediate environment (e.g., home or work) by offering user-friendly interfaces for all sorts of equipment in the home and outside, by taking into account that many older people have impairments in vision, hearing, mobility, or dexterity [20]. To achieve these goals, AAL interlinks, improves, and proposes solutions that combines ICT (Information and Communication Technologies) and social environments.

AAL systems have been developed in the last years for a variety of sub-domains. In Table 2.1 we present a classification of AAL sub-domains proposed by Afsarmanesh [21] as result of the BRAID project [22]. The classification is focused on four different sub-domains that correspond to the main areas of persons life [22]: (i) Independent Living: Assists daily life activities (e.g., medical reminders, living status monitoring) and supports people mobility (e.g., shopping assistance, smart wheelchairs); (ii) Health and Care in Life: Assists patients in health-related activities, e.g., remote health monitoring, emergency assistance, exercise assistance; (iii) Occupation in Life: Supports elders to continue their professional activities; and (iv) Recreation in Life: Facilitates socialization and participation of ageing citizens in social, leisure, learning, and in cultural and political activities.

Table 2.1: Classification of AAL sub-domains. Adapted from Afsarmanesh [21].

First level	Second level	Third level
Independent living	Daily life assistance	Home safety and care Personal activity management
	Supporting physical mobility	Localization/positioning assistance Mobility and transportation
Health and care	Monitoring	Chronic diseases Sensorial supervision
	Rehabilitation and disabilities compensation	Physical compensation Neuro-cognitive compensation

Continued on next page

Table 2.1 – *Continued from previous page*

First level	Second level	Third level
		Rehabilitation
	Caring and intervention	Healthcare management Healthy lifestyle intervention Medication assistance
Occupation in life	Ageing at work	Inter-generational relations Adjusted working space
	Extending professional life	Keeping links former employers Freelancing & entrepreneurship Professional communities
Recreation in life	Socialization	Social events management Virtual communities
	Learning	Remote learning Experiences exchanging
	Entertainment	Recreation activities Cultural activities Gamming

To support and facilitate the development of AAL systems, a range of AAL platforms have been also developed in the last years, principally offering tools, middleware, or general-purpose components. The majority of such platforms have explored the use of well-known and more consolidated technologies and other key technologies, e.g., OSGi [101], which has been considered as one of the most appropriate technologies used as a basis for the development of AAL platforms [31]. Currently, the main AAL platforms are: Alhambra [102], Hydra [104], OASIS [105], OpenAAL [106], PERSONA [107], and UniversAAL [108]. Each platform has been developed for different sub-domains and, correspondingly, has different characteristics [31].

Moreover, in terms of functionality, AAL software systems must be [1]: a) personalizable, i.e., tailored to the users' needs; b) adaptive, i.e., capability to react to the dynamic changes in device/service availability, resource availability, system environment, or user requirements; and c) anticipatory, i.e., anticipating users' desires as far as possible without conscious mediation. Additionally, according to EvAAL [23][2], AAL systems must present the following core functionalities:

- *Sensing*: capability of collecting information from any relevant place (e.g., in-/on-body and in-/on-appliance), or environment (e.g., home, outdoor, vehicles, and public spaces);
- *Reasoning*: aggregation, processing, and analysis of data in order to either infer new data or deduce actions to be performed;

[2]EValuating AAL systems through competitive benchmarking EvAAL [23]

- *Acting*: automatic control of the environment through actuators;
- *Communicating*: communications among sensors, reasoning systems, and actuators, where all these components can be connected dynamically; and
- *Interacting*: interaction between human users and AAL systems by means of personalized interfaces.

In this perspective, in order to develop AAL systems, knowledge provided by a heterogeneous set of disciplines (e.g., advanced human/machine interfaces, sensors, microelectronics, software, web & network technologies, energy generation or harvesting, control technologies, new materials, and robotics) have to be integrated, resulting in systems that must offer user-centered services. Consequently, one of the main concerns of AAL domain is to embrace diverse technological challenges in order to approprately develop AAL systems.

Chapter 3

Related Work

Due to the lack of directly related work (i.e., secondary studies on the quality assessment of AAL systems), in this Chapter we present papers (i.e., systematic reviews, surveys, and experience reports) that analyze quality attributes in application domains similar to AAL, i.e., embedded and healthcare systems.

Firstly, starting with the most generic type of systems in which AAL can be classified, Oliveira et al. [24] present a detailed state of the art about quality models and quality attributes for embedded systems. The findings of that systematic literature review suggested that the most important quality attributes for embedded systems are understandability, reliability, security, safety, functionality, efficiency, portability, and testability.

Regarding the healthcare domain, Mairiza et al. [25] provide a catalog of non-functional requirements (NFRs) and highlight several NFRs (i.e., communicativeness, confidentiality, integrity, performance, privacy, reliability, safety, security, traceability, and usability) as the most frequently considered in this domain. In a similar effort, Wangenheim et al. [26] establish a model to meet quality requirements for asynchronous store-and-forward telemedicine systems. In this work, they defined context completeness, flexibility, time behavior, resource utilization, capacity, co-existence, and interoperability as the most important attributes that such systems must have. Concerning mobile health systems, Akter et al. [27] identified reliability, availability, efficiency, and privacy as the prominent quality characteristics for health services provided over mobile platforms.

Recently, Domínguez-Mayo et al. [28] identified the most studied and used quality characteristics in e-Health systems, following a two-step process. First, they selected two categories of quality characteristics from the ISO/IEC 9126 standard: (i) External/Internal Quality: These characteristics were functionality, suitability, usability, accessibility, reliability, maintainability, continuity, efficiency, and portability. For the functionality characteristic, the sub-characteristics were security, interoperability, accuracy, and compliance; and (ii) Quality in use: Characteristics to measure the effect of using e-Health systems in a specific context. In this category, the quality characteristics were safety, effectiveness, satisfaction, and productivity. Second, they conducted a systematic literature review to identify the level of importance of each quality characteristic in such systems. As a result, functionality, effectiveness, and safety were identified as the most used to develop e-Health systems.

A similar research was made by Aghazadeh et al. [29], who evaluated the effects of software quality characteristics and sub-characteristics on the healthcare indicators: user satisfaction, quality of patient care, clinical workflow and efficiency, care providers communication and information exchange, patient satisfaction, and care costs. The most important health quality indicators in relation to software quality characteristics were established based on a literature review. As contribution, the study of Aghazadeh et al. proposes a model based on ISO/IEC 9126 standard that establishes relations between software quality characteristics and health quality indicators. Relations were evaluated through expert opinion analyses. Some important findings were: (i) software functionality affects directly the quality of patient care; (ii) clinical workflow is influenced by the software efficiency; (iii) communication is affected by software maintainability; (iv) usability and efficiency influence on patient satisfaction; and (v) care costs are affected by software maintainability, efficiency, and reliability.

Finally, we can observe that the identification of the state of the art on quality models and quality attributes for the AAL domain is interesting in order to complement the previous studies conducting until now.

Chapter 4

Systematic Mapping Process

In order to conduct our SM, we followed the process proposed by Kitchenham and Charters [4], as showed in Figure 4.1. In short, this process presents three main phases:

1. Phase 1 - Planning the Mapping: In this phase, the research objectives and the SM protocol are defined. The protocol constitutes a predetermined plan that describes research questions and how the SM will be conducted;
2. Phase 2 - Conducting the Mapping: During this phase, primary studies are identified, selected, and evaluated according to the inclusion and exclusion criteria previously established. For each selected study, data are extracted and synthesized; and
3. Phase 3 - Reporting the Mapping: In this phase, a final report is organized and presented.

The next sections present the two first phases in details.

4.1 Planning the Mapping

In short, the SM protocol contains: (i) research objectives and research questions; (ii) search strategy; (iii) selection criteria (i.e., inclusion and exclusion criteria); (iv) procedures for the studies selection; and (v) data extraction and synthesis method.

4.1.1 Research Objectives & Research Questions

In order to guide the planning of our SM, we adopted the Goal-Question-Metrics (GQM) approach [30], which is considered one of the most powerful approaches for research

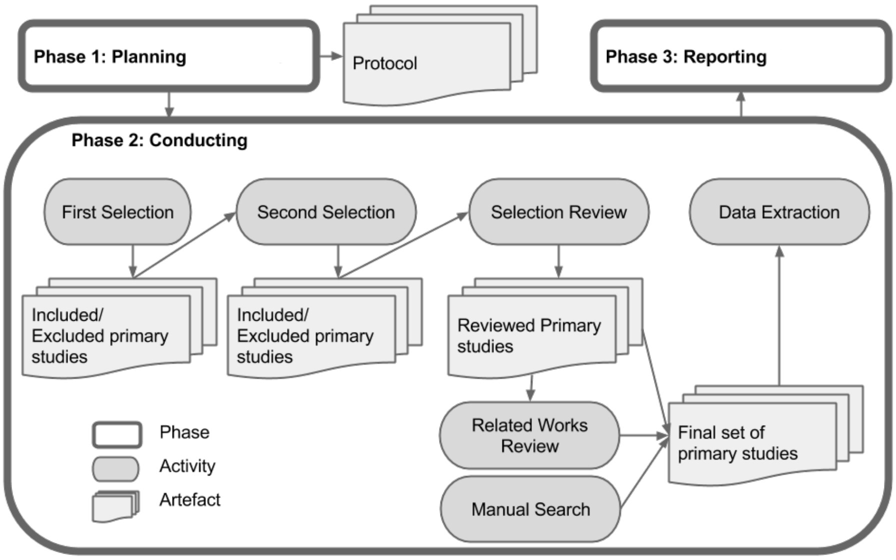

FIGURE 4.1: Systematic Mapping Process. Adapted from [4]

planning. This approach involves three elements: (i) the goal to be achieved; (ii) a set of questions that must be answered to achieve the goal; and (iii) a set of metrics needed to answer the questions.

Regarding our SM, the goal is to provide a broad, detailed state of the art on the existing QMs and QAs for AAL software systems, focused on: (i) which QMs and QAs are the prominent ones in the AAL domain; (ii) how they have been established; and (iii) how they have been evaluated. Based on this goal, three research questions, four subquestions, and related metrics were established, as presented in Table 4.1.

TABLE 4.1: Research Questions and Metrics

Research Questions	Metrics
RQ_1: What are the QMs or QAs proposed for AAL software systems?	(1) QMs or QAs found for AAL software systems; (2) Number of occurrences of each QM or QA found
$RQ_{1.1}$: Which are the critical QAs (e.g., safety, security, performance, and dependability) proposed for AAL software systems?	(1) QAs that are critical for AAL software systems; (2) Number of occurrences of each critical QA
$RQ_{1.2}$: Which are the AAL sub-domains that present QMs or QAs?	(1) AAL sub-domains that present QMs or QAs; (2) Number of occurrences of each QM or QA in each AAL sub-domain; (3) Differences in QMs or QAs across AAL sub-domains
RQ_2: How have QMs or QAs for AAL software systems been established?	(1) Approaches used to establish QMs or QAs; (2) Number of occurrences of each approach

Continued on next page

Table 4.1 – *Continued from previous page*

	Research Questions	Metrics
	$RQ_{2.1}$: Which are the information sources (e.g., personal experience, existing systems or architectures) used to define QMs or QAs for AAL software systems?	(1) Information sources used to define QMs or QAs; (2) Number of occurrences of each information source; (3) The most important information sources
	$RQ_{2.2}$: Are the QMs or QAs presented in a prescriptive (i.e., how quality should be addressed) or descriptive (i.e., how quality has been addressed) manner?	(1) Approach of presenting the QMs or QAs; (2) Number of occurrences of each approach
RQ_3:	How have QMs or QAs for AAL software systems been evaluated?	(1) Approach used (e.g., no evaluation, toy example, case study, experiment, and evaluation in industry); (2) Number of occurrences of each approach

4.1.2 Search strategy

To establish the search strategy for answering the research questions, we initially identified two main keywords: "Ambient Assisted Living" and "Quality Attribute". Subsequently, we identified terms related to these keywords, as presented in Table 4.2.

TABLE 4.2: Keywords and related terms

Keyword	Related terms
"Ambient Assisted Living"	"ambient assisted", "ambient assistance", "assisted environment", "assistive environment", "AAL environment", "independent living", "assisted life", "intelligent living", and "pervasive living".
"Quality attribute"	"quality model", "non-functional property", "non-functional requirement", and "quality requirement".

In addition, we considered the plural form of all keywords and related terms. Afterwards, we used the Boolean operator OR to link the main term and their synonyms; furthermore, all these terms were combined using the Boolean operator AND, resulting in the following search string:

("Ambient Assisted Living" OR "ambient assisted" OR "ambient assistance" OR "assisted environment" OR "assistive environment" OR "AAL environment" OR "independent living" OR "assisted life" OR "intelligent living" OR "pervasive living" OR "assistive environments" OR "AAL environments" OR "assisted environments")

AND

("quality model" OR "quality attribute" OR "non-functional property" OR "non-functional requirement" OR "quality requirement" OR "quality models" OR "quality attributes" OR "non-functional properties" OR "non-functional requirements" OR "quality requirements")

To validate our search string, we defined a control group for our SM. We used two previously known studies, Antonino et al. [31] and Omerovic et al. [32], that were suggested by an AAL expert. They were our baseline to check whether our search string was properly defined, i.e., if our string was able to find these studies in the publication databases.

With the purpose of selecting the most adequate databases for our search, we considered the criteria discussed by Dieste and Padua [33]: (i) content update (publications are regularly updated); (ii) availability (full text of the primary study are available); (iii) quality of results (accuracy of the results obtained by the search); and (iv) versatility to export (since much information are obtained through the search, a mechanism to export the results is required). For our SM we selected six databases (namely ACM Digital Library, IEEE Xplore, ScienceDirect, Scopus, Springer, and Web of Science). According to Dyba et al. [34] and Kitchenham and Charters [4], these publication databases are the most relevant sources in the computer science area.

4.1.3 Selection criteria

The selection criteria were used to assess each primary study obtained from the publication databases, allowing to include relevant studies to answer the research questions, and to exclude non-relevant studies. Our inclusion criteria (IC) and exclusion criteria (EC) were:

- IC_1: The primary study introduces a QM for AAL systems;
- IC_2: The primary study presents one or more QAs that have been reported as important while specifying AAL systems.

- EC_1: The study is a previous version of a more complete one on the same research, of the same authors.
- EC_2: The primary study is a table of contents, short course description, or summary of a conference/workshop.
- EC_3: The primary study is written in a language other than English.
- EC_4: The primary study does not present an abstract or its full text is not available.

4.1.4 Procedure for study selection

In our SM, the selection and evaluation of primary studies were performed in five activities:

First selection: The search string was customized and applied to the selected publication databases. For this, time limits were not placed, and filters on title, abstract, or keywords were also not used in the search. As a result, a set of primary studies possibly related to the research topic was obtained. Based on this set, the title, abstract, and keywords of each primary study was read and the inclusion and exclusion criteria were applied (See Figure 4.1). The introduction and the conclusion sections of each primary study were also considered when necessary. As a result, a set of primary studies potentially relevant was selected.

Second selection: Each primary study selected was read in full and analyzed again considering the inclusion and exclusion criteria (See Figure 4.1). If the decision about the inclusion or exclusion of a study was not clear, this study was analyzed by two reviewers. When a disagreement occured, discussions were conducted.

Selection Review: We tested the reliability of our selection by applying a Visual Text Mining (VTM) technique in SLR, as proposed by Felizardo et al. [35]. This technique supports the exploration and analysis of the set of primary studies selected to ensure that relevant studies were not initially eliminated. This technique offers clues about what studies need to be doubly reviewed for inclusion or exclusion, replacing the random choice strategy defined by Kitchenham and Charters [4]. In this perspective, we used Revis (Systematic Literature Review Supported by Visual Analytics) tool, that enables several VTM capabilities to explore a set of primary studies [36]. The VTM functionalities of Revis that we used were: (i) the creation of content map, i.e., a visual representation of the primary studies, that enables to investigate content and similarity relationships between these studies; (ii) the application of clustering algorithms in order to create primary studies clusters and their respective topics; and (iii) the representation of the studies status, i.e., included or excluded [36]. Figure 4.2 shows four clusters of studies with similarities in title, keywords, and abstract contents. Clusters 2 and 3 contain both included (represented as white circles) and excluded studies (represented as black circles), which means that the four studies into such clusters need to be reviewed to verify the applied selection criteria.

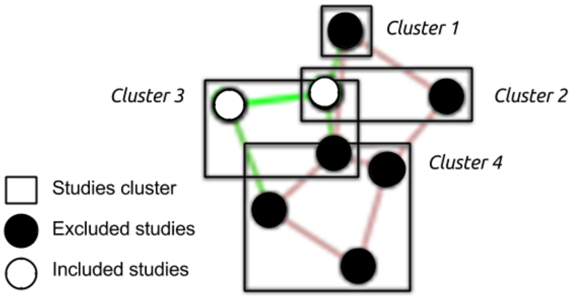

FIGURE 4.2: Clusters of studies using the Revis tool

Related works review: We used the snowball technique [37] intending to cover the whole research area. This technique allowed us to identify and examine works cited in the studies selected in the two previous steps.

Manual search: We used the "Google Scholar" search engine to identify possible studies that were not found neither in data libraries nor in the primary studies' related works.

As result of these five activities, a set of primary studies that can answer our research questions are obtained.

4.2 Data extraction & synthesis strategy

The selected primary studies were underwent through data extraction. More specifically, we used a data extraction form for each primary study. This form also contains data related to each research question, as presented in Table 4.3. The dataset gathered from these forms supported the results synthesis. During the data extraction, data of each primary study was extracted by one researcher involved in this SM. In case of doubt, discussions with other researchers were conducted. To draw conclusions and answer our research questions, we performed qualitative analysis. The mapping between metrics and research questions has already been presented in Table 4.1, therefore it is omitted from this sub-section.

Table 4.3: Data extraction form

General information	
Title	
Authors	
Publication type	[_] Journal Article (JA) [_] Web Page (WP) [_] Chapter of Book (CB) [_] Conference Paper (CP)
Publication databases	[_] ACM [_] IEEE Xplore (IE) [_] Science Direct (SD) [_] Scopus (Sc) [_] Springer (Sp) [_] Web of Science (WS) [_] Related studies (RS) [_] Google Scholar (GS)
Publication year	
RQ_1	
List of quality attributes	
AAL sub-domain	
The QM & QA is oriented to meet critical properties?	[_] Yes [_] No
RQ_2	
Source of information	
Documentation of existing software systems	[_] Yes [_] No
Literature Review	[_] Yes [_] No
Expert opinion	[_] Yes [_] No
Standards and regulations	[_] Yes [_] No
Other, specify:	
Method of development	
Descriptive	[_] Yes [_] No
Prescriptive	[_] Yes [_] No
RQ_3	
Number of systems that applied the QM & QA	
Is the QM & QA currently in use?	[_] Yes [_] No
Evaluation approach	
Industrial use	[_] Yes [_] No
Industrial studies	[_] Yes [_] No
Academic studies	[_] Yes [_] No
Expert opinions or observations	[_] Yes [_] No
Demonstrations or working out toy examples	[_] Yes [_] No

4.3 Conducting the Mapping

Our SM was conducted from August to December 2015. During the conducting phase, primary studies were identified, selected, and evaluated using the inclusion and exclusion criteria. For each selected study, data were extracted and synthetized according to the protocol presented in Section 4.1. Figure 4.3 shows the results for each activity previously described in Section 4.1.4.

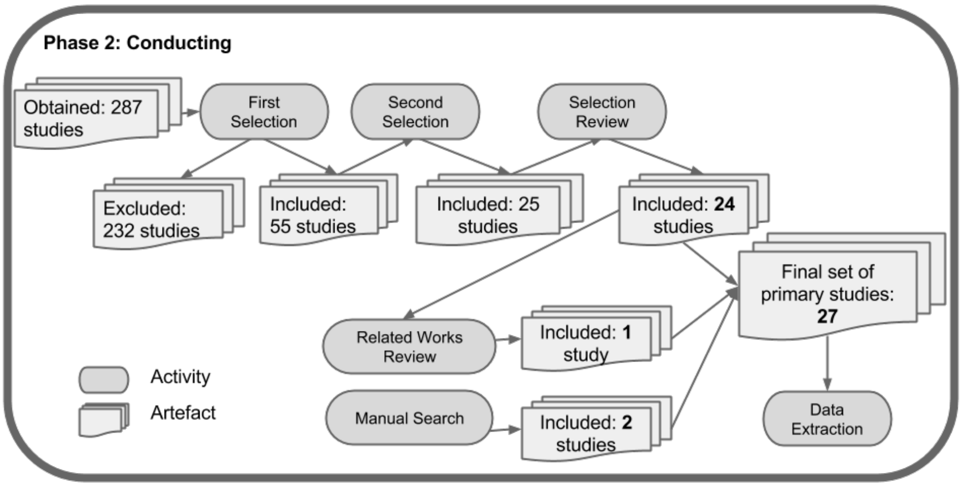

FIGURE 4.3: Search conduction results

4.3.1 First selection

We adapted the search string established during the planning to each publication database. Table 4.4 presents the adapted strings.

TABLE 4.4: Adapted string by publication database.

Publication Database	**String**
ACM	(”Quality Model” or ”Quality Models” or ”Quality Attribute” or ”Quality Attributes” or ”non-functional requirement” or ”non-functional requirements” or ”non-functional property” or ”non-functional properties” or ”quality requirement” or ”quality requirements”) and,(”ambient assisted living” or ”ambient assisted” or ”ambient assistance” or ”assisted environments” or ”assistive environments” or ”assisted environment” or ”assistive environment” or ”AAL environment” or ”AAL environments” or,”independent living” or ”assisted life” or ”intelligent living” or ”pervasive living”)
IEEE Xplore and Springer-Ling	(”Quality Model” OR ”Quality Models” OR ”Quality Attribute” OR ”Quality Attributes” OR ”non-functional requirement” OR ”non-functional requirements” OR ”non-functional property” OR ”non-functional properties” OR ”quality requirement” OR ”quality requirements”) AND,(”ambient assisted living” OR ”ambient assisted” OR ”ambient assistance” OR ”assisted environments” OR ”assistive environments” OR ”assisted environment” OR ”assistive environment” OR ”AAL environment” OR ”AAL environments” OR,”independent living” OR ”assisted life” OR ”intelligent living” OR ”pervasive living”)

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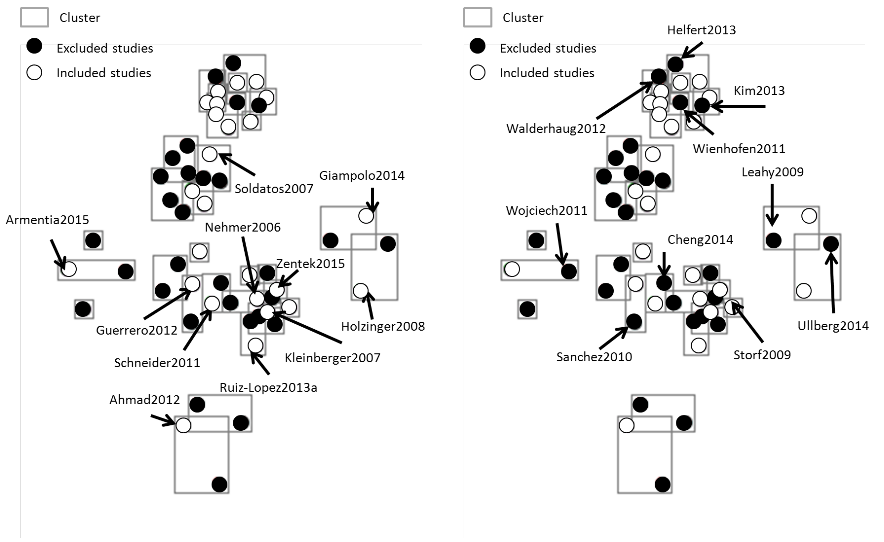
Table 4.4 – *Continued from previous page*

Publication Database	String
Web of Science	TI=((”Quality Model” OR ”Quality Models” OR ”Quality Attribute” OR ”Quality Attributes” OR ”non-functional requirement” OR ”non-functional requirements” OR ”non-functional property” OR ”non-functional properties” OR ”quality requirement” OR ”quality requirements”) AND (”ambient assisted living” OR ”ambient assisted” OR ”ambient assistance” OR ”assisted environments” OR ”assistive environments” OR ”assisted environment” OR ”assistive environment” OR ”AAL environment” OR ”AAL environments” OR ”independent living” OR ”assisted life” OR ”intelligent living” OR ”pervasive living”)) OR TS=((”Quality Model” OR ”Quality Models” OR ”Quality Attribute” OR ”Quality Attributes” OR ”non-functional requirement” OR ”non-functional requirements” OR ”non-functional property” OR ”non-functional properties” OR ”quality requirement” OR ”quality requirements”) AND (”ambient assisted living” OR ”ambient assisted” OR ”ambient assistance” OR ”assisted environments” OR ”assistive environments” OR ”assisted environment” OR ”assistive environment” OR ”AAL environment” OR ”AAL environments” OR ”independent living” OR ”assisted life” OR ”intelligent living” OR ”pervasive living”))
Scopus and ScienceDirect	({Quality Model} OR {Quality Models} OR {Quality Attribute} OR {Quality Attributes} OR {non-functional requirement} OR {non-functional requirements} OR {non-functional property} OR {non-functional properties} OR {quality requirement} OR {quality requirements}) AND ({ambient assisted living} OR {ambient assisted} OR {ambient assistance} OR {assisted environments} OR {assistive environments} OR {assisted environment} OR {assistive environment} OR {AAL environments} OR {AAL environment} OR {independent living} OR {assisted life} OR {intelligent living} OR {pervasive living})

We obtained 302 primary studies and removed duplicate ones (i.e., 15 studies), remaining 287 studies for analysis. To support the management of the primary studies, we used Mendeley [38], a reference management tool that allows storing information on the primary studies (e.g., title, authors, book title, and abstract), as well as the set the exclusion/exclusion criteria applied to select each primary study. As result of this first selection activity, a total of 55 studies were included for detailed inspection, as illustrated in Figure 4.3.

4.3.2 Second selection

The full text of the 55 primary studies was read and the selection criteria were again applied. As a result, 25 primary studies were included and 30 studies were excluded, as shown in Figure 4.3.



(a) Primary studies reviewed for possible exclusion

(b) Primary studies reviewed for possible inclusion

Figure 4.4: Content map with 30 clusters of primary studies using Revis tool.

4.3.3 Selection review

To verify the reliability of the results of the second selection activity (i.e., 25 studies included and 30 excluded), we applied VTM techniques in our SM. Specifically, we used the Revis tool [36] to identify if important primary studies were excluded or if irrelevant ones were included.

A content map was created, as showed in Figure 4.4, containing 30 clusters (represented by rectangles) with the 25 studies included (represented as white circles) and the 30 studies excluded (represented as black circles). Clusters with mixed studies (i.e., included and excluded studies) were observed. Figure 4.4(b) and Figure 4.4(a) highlight the studies that we reviewed again for possible inclusion or exclusion, respectively. Observe that primary studies that were reviewed are in clusters where there are mixed studies (i.e., included and excluded studies). Hence, we reviewed again ten primary studies, which were initially excluded, but possible could be included (See Figure 4.4(b)). Similarly, we also reviewed other eleven primary studies, which were previously included, but possibly could be excluded, as detailed in Figure 4.4(a). For instance, Leahy [88] is found in a cluster with other included studies (see right side of Figure 4.4(b)). Hence, it could be possible included; therefore, it was again reviewed. The same strategy was applied to all other studies.

Complementing information in Figure 4.4, Table 4.5 also lists the primary studies previously included and excluded, and also highlights the studies that were again reviewed to possible inclusion or exclusion. After reviewing the 21 primary studies (11 studies for a possible exclusion, and 10 studies for a possible inclusion), we concluded that one study should be included (Sánchez-Pi and Molina [40]) and two studies should be excluded (Schneider et al. [41] and Soldatos et al. [42]). As a result, 24 primary studies remained for the data extraction.

TABLE 4.5: List of primary studies included and excluded after reviewing

Included	Excluded
Ahmad et al. (2012) [49]	Aizpurua et al. (2013) [73]
Antonino et al. (2011) [31]	AlRomi et al. (2013) [74]
Armentia et al. (2015) [59]	Armentia et al. (2015a) [75]
Arning et al. (2015) [60]	Benghazi et al. (2009) [76]
Giampaolo et al. (2014) [57]	Benghazi et al. (2012) [77]
Gómez-Martínez et al. (2015) [62]	Breiner et al. (2011) [78]
Guerrero et al. (2012) [51]	Caliz et al. (2014) [79]
Holzinger et al. (2008) [48]	Cheng et al. (2009) [80]
Hossain et al. (2011) [50]	Cheng et al. (2014) [81]
Kleinberger et al. (2007) [47]	Dasios et al. (2015) [82]
Luor et al. (2015) [63]	Emiliani et al. (2011) [83]
Mangano et al. (2015) [64]	Gui et al. (2011) [84]
McNaull et al. (2012) [52]	Helfert et al. (2013) [87]
Memon et al. (2014) [56]	Kim et al. (2013) [85]
Nehmer et al. (2006) [46]	Klompmaker et al. (2011) [86]
Omerovic et al. (2013) [32]	Leahy et al. (2009) [88]
Ruiz-Lopez et al. (2012) [53]	Naranjo et al. (2009) [89]
Ruiz-Lopez et al. (2013a) [54]	Rodrigues et al. (2012) [90]
Salvi et al. (2014) [58]	Ruiz-Lopez et al. (2013) [91]
Schneider et al. (2011) [41]+	Ruiz-Lopez et al. (2013b) [92]
Solaimani et al. (2013) [55]	Sanchez et al. (2010) [40]*
Soldatos et al. (2007) [42]+	Senart et al. (2006) [93]
Stengler et al. (2015) [65]	Spanoudakis et al. (2011) [100]
Zentek et al. (2015) [66]	Storf et al. (2009) [94]
Beevi et al. (2015) [61]	Ullberg et al. (2014) [95]
	Wagner et al. (2013) [6]
	Walderhaug et al. (2012) [96]
	Walderhaug et al. 2013 [97]
	Wienhofen et al. 2011 [98]
	Wojciechowski et al. 2011 [99]

* Included after reviewing

\+ Excluded after reviewing

4.3.4 Related works review

We applied the snowball technique [37] looking for works cited in the 24 selected primary studies. Among all works evaluated, we selected one relevant primary study (Ras et al. [43]), which had not been previously identified.

4.3.5 Manual search

Moreover, we made a search using Google scholar search engine and we identified two relevant primary studies, Schneider et al. [44] and Queirós et al. [45]. .

Finally, a set of 27 studies, presented in Table 4.6, was selected as the relevant ones for our SM. Column "Type" indicates if the primary study was published as a Journal Article (JA), Chapter of Book (CB), Conference Paper (CP), or Web Page (WP). Column "IC" describes the criterion used to include the studies. Column "DL" shows the database where each study was obtained: ACM (ACM), IEEE Xplore (IE), Science Direct (SD), Scopus (Sc), Springer (Sp), Web of Science (WS), and Google Scholar (GS). Moreover, reference search (RS) indicates that we found the study by applying the snowball technique.

TABLE 4.6: Final list of primary studies selected to data extraction

ID	Title	Reference	Type	IC	DL
S1	Living Assistance Systems: An Ambient Intelligence Approach.	Nehmer et al. (2006) [46]	CP	IC2	ACM
S2	Ambient Intelligence in Assisted Living: Enable Elderly People to Handle Future Interfaces	Kleinberger et al. (2007) [47]	CB	IC2	Sp
S3	Engineering Tele-Health Solutions in the Ambient Assisted Living Lab	Ras et al. (2007) [43]	CP	IC2	RS
S4	Investigating Usability Metrics for the Design and Development of Applications for the Elderly	Holzinger et al. (2008) [48]	CB	IC2	Sp
S5	Adaptation of an Evaluation System for e-Health Environments	Sánchez-Pi and Molina (2010) [40]	CB	IC2	Sp
S6	Evaluation of AAL Platforms According to Architecture-Based Quality Attributes	Antonino et al.(2011) [31]	CB	IC2	Sc Sp WS
S7	Modeling and Assessing Quality of Information in Multisensor Multimedia Monitoring Systems	Hossain et al. (2011) [50]	JA	IC2	ACM
S8	Using RELAX, SysML and KAOS for Ambient Systems Requirements Modeling	Ahmad et al. (2012) [49]	CP	IC2	WS
S9	An Indoor Navigation System for the Visually Impaired	Guerrero et al. (2012)[51]	JA	IC2	Sc
S10	Data and Information Quality Issues in Ambient Assisted Living Systems	McNaull et al. (2012) [52]	JA	IC2	ACM
S11	Towards a Reusable Design of a Positioning System for AAL Environments	Ruiz-López et al. (2012) [53]	CB	IC2	Sc Sp WS
S12	OptimAAL Quality Model	Schneider et al. (2012) [44]	WP	IC1	GS
S13	Elicitation of Quality Characteristics for AAL Systems and Services	Omerovic et al. (2013) [32]	JA	IC2	Sc Sp

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Table 4.6 – *Continued from previous page*

ID	Title	Reference	Type	IC	DL
S14	Usability, Accessibility and Ambient Assisted Living: A Systematic Literature Review	Queirós et al. (2013) [45]	JA	IC2	GS
S15	Requirements Systematization through Pattern Application in Ubiquitous Systems	Ruiz-López et al. (2013a) [54]	JA	IC2	Sc
S16	Critical Design Issues for the Development of Smart Home Technologies	Solaimani et al. (2013) [55]	JA	IC2	Sc
S17	Ambient Assisted Living Healthcare Frameworks, Platforms, Standards, and Quality Attributes.	Memon et al. (2014) [56]	JA	IC2	Sc
S18	The Challenges Behind Independent Living Support Systems	Giampaolo et al. (2014) [57]	CB	IC2	Sp
S19	A framework for Evaluating Ambient Assisted Living Technologies and the Experience of the universAAL Project	Salvi et al. (2014) [58]	JA	IC2	Sc
S20	Flexibility Support for Homecare Applications Based on Models and Multi-Agent Technology	Armentia et al. (2015) [59]	JA	IC2	Sc
S21	"Get that Camera Out of My House!" Conjoint Measurement of Preferences for Video-Based Healthcare Monitoring Systems in Private and Public Places.	Arning et al. (2015) [60]	CB	IC2	Sp
S22	Data Quality Oriented Taxonomy of Ambient Assisted Living Systems	Beevi et al. (2015) [61]	CP	IC2	IE
S23	A Semantic Approach for Designing Assistive Software Recommender Systems	Gómez-Martínez et al. (2015) [62]	JA	IC2	Sc
S24	Exploring the Critical Quality Attributes and Models of Smart Homes	Luor et al. (2015) [63]	JA	IC2	Sc
S25	Bridge: Mutual Reassurance for Autonomous and Independent Living	Mangano et al. (2015) [64]	JA	IC2	Sc
S26	Towards the Deployment of Open Platform AAL Services in Real Life-Advantages and Lessons Learned uSmAAL: A Case Study for Implementing Intelligent AAL Services in Real Life based on the Open Platform universAAL	Stengler et al. (2015) [65]	CP	IC2	Sc
S27	Which AAL Middleware Matches my Requirements? An Analysis of Current Middleware Systems and a Framework for Decision-Support	Zentek et al. (2015) [66]	CB	IC2	Sp

It is important to notice that we just found one study (S12) that proposed a QM for AAL systems, i.e., included by IC1. The majority of studies (96,3%, 26/27) provide sets of QAs for AAL systems, i.e., studies included by IC2. Moreover, all studies were published in the last ten years, which might indicate an increasing interest for this research topic.

4.4 Quality Assessment

To analyze the quality of each included primary study, we established a checklist containing seven questions (or quality criteria), based on the quality assessment of primary studies proposed by Kitchenham and Charters [4]:

- Q1: Is there a rationale for why the study was undertaken?
- Q2: Is an overview about the state of the art of the area in which the study is developed presented?
- Q3: Is there an adequate description of the context in which the work was carried out?
- Q4: Is a clear justification about the methods used during the study provided?
- Q5: Are there a clear statement of contributions and sufficient data to support them?
- Q6: Are the credibility and limitations of their findings explicitly discussed?
- Q7: Are the perspectives of future works discussed?

Table 4.7 presents the scores obtained by each primary study. For each question, the following scale-point was applied: (i) the study fully meets a given quality criterion (1 point); (ii) the study meets the quality criterion to some extent (0.5 point); and (iii) the study does not meet this quality criterion (0 point). The total quality score of each study can fell into the range between: 0 - 1.0 (very poor); 1.1 - 2.0 (poor); 2.1 - 3.0 (fair); 3.1 - 4.0 (average), 4.1 - 5.0 (good), 5.1 - 6.0 (very good), and 6.1 - 7.0 (excellent).

Table 4.7: Quality Assessment of Primary Studies

Study	**Quality Question**							**Study Overal Score**	
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	(Total)	Quality
S16	1	1	1	1	1	1	1	7.0	Excellent
S19	1	1	1	1	1	1	1	7.0	Excellent
S20	1	1	1	1	1	1	1	7.0	Excellent
S9	1	1	1	1	0.5	1	1	6.5	Excellent
S13	1	0.5	1	1	1	1	1	6.5	Excellent
S21	1	1	1	1	1	0.5	1	6.5	Excellent

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Table 4.7 – *Continued from previous page*

Study	**Quality Question**							**Study Overal Score**	
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	(Total)	Quality
S7	1	1	1	1	1	0	1	6.0	Very Good
S11	0	1	1	1	1	1	1	6.0	Very Good
S22	1	1	1	1	1	1	0	6.0	Very Good
S23	1	1	1	1	1	0	1	6.0	Very Good
S24	1	1	1	1	1	0.5	0.5	6.0	Very Good
S26	1	1	1	1	1	0.5	0.5	6.0	Very Good
S12	1	0.5	1	1	1	0.5	0.5	5.5	Very Good
S14	1	0	1	0.5	1	1	1	5.5	Very Good
S25	1	1	1	0.5	1	0.5	0.5	5.5	Very Good
S6	1	0	0.5	0.5	1	1	1	5.0	Good
S17	1	1	1	1	1	0	0	5.0	Good
S27	1	1	1	1	1	0	0	5.0	Good
S2	0.5	0	1	1	0.5	0.5	1	4.5	Good
S3	1	0	1	0.5	0.5	0	1	4.0	Average
S4	1	1	0.5	0.5	0.5	0	0.5	4.0	Average
S10	1	1	1	0.5	0.5	0	0	4.0	Average
S5	0.5	0.5	0.5	1	0.5	0	0.5	3.5	Average
S8	1	1	0	0.5	1	0	0	3.5	Average
S15	1	0	0.5	0	1	0	0.5	3.0	Fair
S18	0.5	0.5	1	0.5	0.5	0	0	3.0	Fair
S1	0.5	1	0.5	0	0.5	0	0	2.5	Fair

Nineteen out of 27 studies present good quality, i.e., S9, S13, S16, S19, S20, and S21 can be categorized with excellent quality; S7, S11, S12, S14, S22, S23, S24, S25, and S26 have very good quality; and S2, S6, S17, and S27 have good quality. Moreover, five studies (S3, S4, S5, S8, and S10) have average quality, and three studies (S1, S15 and S18) can be considered as having fair quality. Therefore, we considered all 27 studies to extract information to answer our research questions.

Aiming to assess the quality of primary studies we defined seven criteria. We evaluated each primary study regarding such criteria and we considered that all studies had enough quality to be considered in our SM. However, it might be possible that scores assignment has been influenced by the opinion of the reviewers.

Chapter 5

Conclusion and Future Work

The adoption of quality models and the identification of the most important quality attributes can contribute to the improvement on the quality of AAL software systems. In this perspective, the main contribution of this work is to present a detailed state of the art on the quality models and quality attributes that are available in literature, which can orient the development of AAL software systems with more quality. It was also presented the major quality attributes addressed currently for AAL, the way they were defined and evaluated, and the AAL sub-domains where they were proposed. For this, we conducted the steps of a systematic mapping.

As future work, we intent to make a more specific investigation of this research area, for instance, identifying metrics associated to each quality attribute, and characterizing the quality attributes addressed in current reference architectures in the AAL domain. Furthermore, the results of this SM intend to support the consolidation of a more complete quality model for the AAL domain, aiming at contributing to a more effective development of successful AAL software systems.

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Bibliography

[1] Broek, G.V.D., Cavallo, F., & Wehrmann, C. (2010). *AALIANCE Ambient Assisted Living Roadmap.* IOS Press, Amsterdam, The Netherlands.

[2] Nakagawa, E.Y., Antonino, P.O., Becker, M., Maldonado, J.C., Storf, H., Villela, K.B., & Rombach, E. (2013). Relevance and perspectives of AAL in Brazil. *Journal of Systems and Software*, 86(4),985–996.

[3] Aguiar, A., Filho, S.J., Magalhães, S.J., Casagrande, T.D., & Hessel, F. (2010). Hellfire: A design framework for critical embedded systems' applications. In *ISQED '10: 11th International Symposium on Quality Electronic Design*, (pp. 730–737).

[4] Kitchenham, B.A., & Charters, S. (2007). Guidelines for performing systematic literature reviews in software engineering. Technical Report EBSE 2007-001., Keele University and Durham University, UK.

[5] Deissenboeck, F., Juergens, E., Lochmann, K., & Wagner, S. (2009). Software quality models: Purposes, usage scenarios and requirements. In *ICSE '09: 7th International Conference on Software Engineering* (pp. 9–14).

[6] Wagner, S. Hansen, F. O. Pedersen, C. F. Memon, M. Aysha, F. H. Mathissen, M. Nielsen, C. & Wesby, O. L. (2013). Carestore platform for seamless deployment of ambient assisted living applications and devices. In *PervasiveHealth '13: 7th International Conference on Pervasive Computing Technologies for Healthcare* (pp. 240–243).

[7] International standard ISO/IEC/IEEE 24765 (2010). Systems and software engineering – Vocabulary (First edition).

[8] McCall, J.A., Richards, P.K., & Walters, G.F. (1977). Factors in Software Quality. Technical report, General Electric Co, Sunnyvale, CA.

[9] Boehm,B.W., Brown, J.R., & Lipow, M. (1976). Quantitative evaluation of software quality. In *ICSE'76: 2nd International Conference on Software Engineering* (pp. 592–605).

[10] ISO/IEC 9126-1 (2001). Software engineering – Product quality. http://www.iso.org/iso/catalogue_detail.htm?csnumber=22749. Accessed 18th January 2016.

[11] ISO/IEC 25010 (2011). Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - System and software quality models. https://www.iso.org/obp/ui/#iso:std:iso-iec:25010:ed-1:v1:en. Accessed 18th January 2016.

[12] ISO/IEC 25012 (2008). Software engineering – Software product Quality Requirements and Evaluation (SQuaRE) – Data quality model https://http://www.iso.org/iso/catalogue_detail.htm?csnumber=35736. Accessed 20th January 2016.

[13] Oman, P. & Hagemeister, J. (1992). Metrics for assessing a software system's maintainability. In *CSM '92: Conference on Software Maintenance* (pp. 337–344).

[14] Welker, K. D. (2001). The Software Maintainability Index Revisited. *CrossTalk. The Journal of Defense Software Engineering*, 18–21.

[15] Laval, J., Bergel, A., & Ducasse, S. (2008). Assessing the quality of your software with MoQam. In *FAMOOSr '08: 2nd Workshop on FAMIS and Moose Reengineering*, (pp. 1–4).

[16] Goyal, P.K. & Joshi, G. (2014). QMOOD metric sets to assess quality of Java program. In *ICICT'14: International Conference on Issues and Challenges in Intelligent Computing Techniques*, (pp. 520–533).

[17] Bansiya, J. & Davis, C. G. (2002). A hierarchical model for object-oriented design quality assessment. *IEEE Transactions on Software Engineering*, 28(1), 4–17.

[18] Zeephongsekul, P., Xia, G., & Kumar, S. (1994). Software-reliability growth model: primary-failures generate secondary-faults under imperfect debugging. *IEEE Transactions on Reliability*, 43(3),408–413.

[19] Ahmad, K. (2011). A Software Reliability Growth Model. *Journal of Modern Mathematics and Statistics*, 5(1),13–16.

[20] Pieper, M., Antona, M., & Cortes, U. (2011). Introduction to the Special theme - Ambient Assisted Living. *Ercim News*. http://ercim-news.ercim.eu/en87/special. Accessed 10th January 2016.

[21] Afsarmanesh, H. (2011). BRAID project. D4.2 Consolidated Vision of ICT and Ageing. Universiteit van Amsterdam. http://braidproject.eu/sites/default/files/D4.2%20Final.pdf. Accessed 10th January 2016.

[22] BRAID project - Bridging Research in Ageing and ICT Development. http://www.braidproject.eu/. Accessed 22 January 2016.

[23] EvAAL. (2014). Evaluating AAL Systems through Competitive Benchmarking. URL http://evaal.aaloa.org/. Accessed 4th January 2016.

[24] Oliveira, L. B., Guessi, M., Feitosa, D., Manteuffel, C., Galster, M., Oquendo, F., & Nakagawa, E. Y. (2013). An Investigation on Quality Models and Quality Attributes for Embedded Systems. In *ICSEA '13: 8th International Conference on Software Engineering Advances.* (pp. 1–6).

[25] Mairiza, D., Zowghi, D., & Nurmuliani, N. (2010). An investigation into the notion of non-functional requirements. In *SAC '10: 25th Symposium on Applied Computing.* (pp. 311–317).

[26] Wangenheim, C., Hauck, J., & Buglione, L. (2013). Tailoring software process capability/maturity models for the health domain. *Health and Technology*, 3(1), 11–28.

[27] Akter, S., D' Ambra, J., & Ray, P. (2010). Service quality of mHealth platforms: development and validation of a hierarchical model using PLS. *Electronic Markets*, 20(3-4),209–227.

[28] Domínguez-Mayo, F. J., Escalona, M. J., Mejías, M., Aragón, G., García-García, J. A., Torres, J., & Enríquez, P. (2015). A Strategic Study about Quality Characteristics in e-Health Systems Based on a Systematic Literature Review. *The Scientific World Journal*, 2015,(863591),1–11.

[29] Aghazadeh, S., Pirnejad, H., Aliev, A., & Moradkhani, A. (2015). Evaluating the Effect of Software Quality Characteristics on Health Care Quality Indicators. *Journal of Health Management & Informatics*, 2,(3),67–73.

[30] Basili, V., Caldiera, G., Rombach, H. (2002). Goal Question Metric Approach. *Encyclopedia of Software Engineering.* John Wiley & Sons, Inc.,528–532.

[31] Antonino, P. O., Schneider, D., Hofmann, C., & Nakagawa, E. Y. (2011). Evaluation of AAL platforms according to architecture-based quality attributes. In Keyson, D., Maher, M., Streitz, N., Cheok, A., Augusto, J., Wichert, R., Englebienne, G., Aghajan, H., & Krose, B., (Eds.), *Ambient Intelligence, Lecture Notes in Computer Science* (Vol. 7040, pp. 264–274). Springer Berlin Heidelberg.

[32] Omerovic, A., Kofod-petersen, A., Solhaug, B., & Svagaard, I. (2013). Elicitation of Quality Characteristics for AAL Systems and Services. *Advances in Intelligent Systems and Computing*, 219,95–104.

[33] Dieste, O., & Padua, O.A.G. (2007). Developing Search Strategies for Detecting Relevant Experiments for Systematic Reviews. In *ESEM '07: 1st International Symposium on Empirical Software Engineering and Measurement* (pp. 215–224).

[34] Dyba, T., Dingsoyr, T., & Hanssen, G. (2007). Applying Systematic Reviews to Diverse Study Types: An Experience Report. In *ESEM '07: 1st International Symposium on Empirical Software Engineering and Measurement.* (pp. 225–234).

[35] Felizardo, K., Andery, G., Paulovich, F., Minghim, R., & Maldonado, J. C. (2012). A visual analysis approach to validate the selection review of primary studies in systematic reviews. *Information and Software Technology*, 54(10),1079–1091.

[36] Scannavino, K.R.F. (2012). *Evidence-based software engineering: systematic literature review process based on visual text mining.* PhD thesis, Instituto de Ciências Matemáticas e de Computação, Universidade de São Paulo, São Carlos. pp. 1–243.

[37] Ridley, D. (2012). *The Literature Review: A Step-by-Step Guide for Students.* SAGE Study Skills Series. SAGE Publications Ltd., 2nd edition.

[38] Mendeley (2014). Reference Manager. http://www.mendeley.com/. Accessed 10th January 2016.

[88] Leahy, D. & Dolan, D. (2009). Digital Literacy – Is It Necessary for eInclusion? In Holzinger, A., & Miesenberger, K., (Eds.), *HCI and Usability for e–Inclusion, Lecture Notes in Computer Science* (Vol. 5889, pp. 149–158). Springer Berlin Heidelberg.

[40] Sánchez-Pi, N., & Molina, J. (2010). Adaptation of an Evaluation System for e-Health Environments. In Setchi, R., Jordanov, I., Howlett, R. J., & Jain, L. C., (Eds.), *Knowledge-Based and Intelligent Information and Engineering Systems, Lecture Notes in Computer Science* (Vol. 6279, pp. 357–364). Springer Berlin Heidelberg.

[41] Schneider, D., Becker, M., & Trapp, M. (2011). Approaching runtime trust assurance in open adaptive systems. In *SEAMS '11: 6th International Symposium on Software Engineering for Adaptive and Self-Managing Systems* (pp. 196–201).

[42] Soldatos, J., Dimakis, N., Stamatis, K., & Polymenakos,L. (2007). A breadboard architecture for pervasive context-aware services in smart spaces: middleware components and prototype applications. *Personal Ubiquitous Computing*, 11(3),193–212.

[43] Ras, E., Becker, M., & Koch, J. (2007). Engineering Tele-Health Solutions in the Ambient Assisted Living Lab. In *AINAW '07: 21st International Conference on Advanced Information Networking and Applications Workshops.* pp. 804-809.

[44] Schneider, D., Kleinberger, T., & Hofmann, C. (2012). Produktqualitin̂ AAL-Systemen. http://www.aal--kompetenz.de/cms/index.php/qualitaetsmodell. Accessed 5th November 2015.

[45] Queirós, A., Silva, A., Alvarelhão, J., Rocha, N., & Teixeira, A. (2013). Usability, accessibility and ambient-assisted living: a systematic literature review. *Universal Access in the Information Society*, 1–10.

[46] Nehmer, J., Becker, M., Karshmer, A., & Lamm, R. (2006). Living assistance systems: an ambient intelligence approach. In *ICSE '06: 28th International Conference on Software Engineering* (pp. 43–50).

[47] Kleinberger, T., Becker, M., Ras, E., Holzinger, A., & Müller, P. Ambient Intelligence in Assisted Living: Enable Elderly People to Handle Future Interfaces. In Stephanidis, C. (Ed.), *Universal Access in Human-Computer Interaction. Ambient Interaction, Lecture Notes in Computer Science*, (Vol. 4555, pp. 103–112). Springer Berlin Heidelberg.

[48] Holzinger, A., Searle, G., Kleinberger, T., Seffah, A., & Javahery, H. (2008). Investigating Usability Metrics for the Design and Development of Applications for the Elderly. In Miesenberger, K., Klaus, J., Zagler, W., & Karshmer, A. (Eds.), *Computers Helping People with Special Needs, Lecture Notes in Computer Science* (Vol. 5105, pp. 98–105). Springer Berlin Heidelberg.

[49] Ahmad, M., Bruel, J.M., Laleau, R., & Gnaho, C. (2012). Using RELAX, SysML and KAOS for Ambient Systems Requirements Modeling. In Shakshuki, E., & Younas, M. (Eds.), *Procedia Computer Science (ANT/MOBIWIS)* (Vol. 10, pp. 474–481).

[50] Hossain, M. A., Atrey, P. K., & Saddik, A. (2011). Modeling and assessing quality of information in multisensor multimedia monitoring systems. *ACM Transactions on Multimedia Computing, Communications, and Applications*, 7(1),3:1–3:30.

[51] Guerrero, L.A., Vasquez, F., & Ochoa, S.F. (2012). An indoor navigation system for the visually impaired. *Sensors*, 12(6),8236–8258.

[52] McNaull, J., Augusto, J., Mulvenna, M., & McCullagh, P. (2012). Data and Information Quality Issues in Ambient Assisted Living Systems. *Journal of Data and Information Quality*, 4(1),4:1–4:15.

[53] Ruiz-López, T., Noguera, M., Rodríguez-Fórtiz, M.J., & Garrido, J.L. (2012). Towards a Reusable Design of a Positioning System for AAL Environments. In Chessa,

S. & Knauth, S. (Eds.), *Evaluating AAL Systems Through Competitive Benchmarking. Indoor Localization and Tracking, Communications in Computer and Information Science* (Vol. 309, pp. 65–79). Springer Berlin Heidelberg.

[54] Ruiz-López, T., Noguera, M., Rodríguez-Fórtiz, M.J., & Garrido, J.L. (2013a). Requirements Systematization through Pattern Application in Ubiquitous Systems. *Advances in Intelligent Systems and Computing*, 219,17–24.

[55] Solaimani, S., Bouwman, H., & Secomandi, F. (2013). Critical design issues for the development of Smart Home technologies. *Journal of Design Research*, 11(1), 72–90.

[56] Memon, M., Wagner, S., Pedersen, C., Beevi, F., & Hansen, F. (2014). Ambient assisted living healthcare frameworks, platforms, standards, and quality attributes. *Sensors*, 14(3),4312–4341.

[57] Giampaolo B., Pekka J., and Jussi L. (2014). The Challenges behind Independent Living Support Systems In Ślzak, D., Schaefer, G., Vuong, S.T., and Kim, Y.S. (Eds.), *Active Media Technology*, Lecture Notes in Computer Scineces, 8610, (pp. 464–474).

[58] Salvi, D., Montalva, J.B., Arredondo, M.T., Prazak-Aram, B., and Mayer, C. (2014). A framework for evaluating Ambient Assisted Living technologies and the experience of the universAAL project *Journal of Ambient Intelligence and Smart Environments. IOS Press.*, 0, (2014), 1–23.

[59] Armentia, A., Gangoiti, U., Priego, R., Estevez, E., and Marcos, M. (2015). Flexibility Support for Homecare Applications Based on Models and Multi-Agent Technology *Sensors*, 15, 31939–31964.

[60] Arning, K. and Ziefle, M. (2015). "Get that Camera Out of My House!" Conjoint Measurement of Preferences for Video-Based Healthcare Monitoring Systems in Private and Public Places. In: Geissbuhler, A., Demongeot, J., Mokhtari, M., Abdulrazak, B., and Aloulou, A. Inclusive Smart Cities and e-Health. Lecture Notes in Computer Sciences,9102, 152–164.

[61] Beevi, F.H.A., Wagner, S., Hallerstede, S., Pedersen, C.F.(2015). Data Quality Oriented Taxonomy of Ambient Assisted Living Systems. In TechAAL'15: IET International Conference on Technologies for Active and Assisted Living (pp. 1–6).

[62] Gómez-Martínez, E., Linaje, M., Sánchez-Figueroa, F., Iglesias-Pérez, A., Preciado, J.C., González-Cabero, J.G., Merseguer, J. (2015). A semantic approach for designing Assistive Software Recommender systems. *The Journal of Systems and Software*, 104, 166–178.

[63] Luor, T., Lu, H.P., Yu, H., Lu, Y. (2015). Exploring the critical quality attributes and models of smart homes. *Maturitas*, 82, 377–386.

[64] Mangano, S., Saidinejad, H., Veronese, F., Comai, S., Matteucci, M., and Salice, F. (2015). Bridge: Mutual Reassurance for Autonomous and Independent Living. *IEEE Intelligent Systems*, 30, 4, 31–38.

[65] Stengler J., Gaikward G. and Ben Hmida H.(2015). Towards the Deployment of Open Platform AAL Services in Real Life-advantages and Lessons Learned - uS-mAAL: A Case Study for Implementing Intelligent AAL Services in Real Life based on the Open Platform universAAL. In ICT4AgeingWell'15: 1st International Conference on Information and Communication Technologies for Ageing Well and e-Health, (pp.67-74).

[66] Zentek, T., Yumusak, C.O., Reichelt, C., and Rashid, A. (2015). Which AAL Middleware matches my requirements? An Analysis of Current Middleware Systems and a Framework for Decision-Support. In Wichert, R., and Klausing, H. (Eds.). Ambient Assisted Living. (pp. 111–125).

[67] Feitosa, D. (2014). *An Architecture Design Method for Critical Embedded Systems.* Proceedings of the WICSA 2014 Companion Volume, Article No. 15, pp. 1-3.

[68] Bianchi, T., Soares, D., and Felizardo, K. R. (2015). Quality attributes of systems-of-systems: a systematic literature review. In SESoS '15: Third International Workshop on Software Engineering for Systems-of-Systems. IEEE Press, Piscataway, NJ, USA, 23-30.

[69] Cook, E. J., Augusto, J.C., & Jakkula, V. R. (2009). Ambient intelligence: Technologies, applications, and opportunities. *Pervasive and Mobile Computing*, 5(4), 277–298.

[70] European Commission. Technology Readiness Levels (TRL), HORIZON 2020 - WORK PROGRAMME 2014-2015 General Annexes, Extract from Part 19 - Commission Decision C(2014)4995. http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf. Accessed 10th October 2015.

[71] Oreizy, P., Gorlick, M. M., Taylor, R. N., Heimbigner, D., Johnson, G., Medvidovic, N., Quilici, A., Rosenblum, D. S., & Wolf, A. L. (1999). An architecture-based approach to self-adaptive software. *IEEE Intelligent Systems*, 14(3), 54–62.

[72] Becker, M. (2008). Software Architecture Trends and Promising Technology for Ambient Assisted Living Systems. In *Assisted Living Systems – Models, Architectures and Engineering Approaches* (pp. 1–18).

[73] Aizpurua, A.; Cearreta, I.; Gamecho, B.; Mi nn, R.; Garay-Vitoria, N.; Gardeazabal, L., Abascal, J. Martn, E.; Haya, P. A. Carro, R. M. (Eds.) Extending In-Home User and Context Models to Provide Ubiquitous Adaptive Support Outside the Home User Modeling and Adaptation for Daily Routines, Springer London, 2013, 25-59

[74] Afnan AlRomi Ghadah AlOfisan, N. A. S. A. A. A.-w. Requirements Engineering of Ambient Assisted Living Technologies for People with Alzheimers Communications in Computer and Information Science, 2015, 529, 381-387

[75] Armentia, A.; Gangoiti, U.; Estevez, E. & Marcos, M. A Multi-Agent Based Approach to Support Adaptability in Home Care Applications IFAC-PapersOnLine, 2015, 48-10, 1-6

[76] Benghazi, K.; Hurtado, M. V.; Rodrguez, M. L. & Noguera, M. Applying formal verification techniques to ambient assisted living systems Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 2009, 5872 LNCS, 381-390

[77] Benghazi, K.; Hurtado, M. V.; Hornos, M. J.; Rodrguez, M. L.; Rodrguez-Domnguez, C.; Pelegrina, A. B. & Rodrguez-Frtiz, M. J. Enabling correct design and formal analysis of Ambient Assisted Living systems Journal of Systems and Software, 2012, 85, 498-510

[78] Breiner, K.; Meixner, G.; Rombach, D.; Seissler, M. & Zhlke, D. Knig, A.; Dengel, A.; Hinkelmann, K.; Kise, K.; Howlett, R. J. & Jain, L. C. (Eds.) Efficient Generation of Ambient Intelligent User Interfaces Knowledge-Based and Intelligent Information and Engineering Systems, Springer Berlin Heidelberg, 2011, 136-145

[79] Caliz, D. & Alaman, X. Pecchia, L.; Chen, L. L.; Nugent, C. & Bravo, J. (Eds.) Ambient Assisted Living and Daily Activities Usability Evaluation Method for Mobile Applications for the Elderly: A Methodological Proposal Springer, 2014, 8868, 252-260

[80] Cheng, B. H. C.; Sawyer, P.; Bencomo, N. & Whittle, J. Schrr, A. & Selic, B. (Eds.) A Goal-Based Modeling Approach to Develop Requirements of an Adaptive System with Environmental Uncertainty Model Driven Engineering Languages and Systems, Springer Berlin Heidelberg, 2009, 468-483

[81] Cheng, B. H. C.; Eder, K. I.; Gogolla, M. & Grunske, L. Bencomo, N.; France, R.; Cheng, B. H. C. & Amann, U. (Eds.) Models@run.time. Foundations, Applications, and Roadmaps Using Models at Runtime to Address Assurance for Self-Adaptive Systems Springer, 2014, 101-136

[82] Dasios, A.; Gavalas, D.; Pantziou, G. & Konstantopoulos, C. Hands-On Experiences in Deploying Cost-Effective Ambient-Assisted Living Systems Sensors, 2015, 15, 14487-14512

[83] Emiliani, P. L.; Burzagli, L. & Gabbanini, F. Stephanidis, C. (Ed.) Universal Access in Ambient Intelligent Environments: A Research Agenda Universal Access in Human-Computer Interaction. Context Diversity, Springer Berlin Heidelberg, 2011, 153-16

[84] Gui, N.; De Florio, V.; Sun, H.; Blondia, C. & Florio, V. D. Toward architecture-based context-aware deployment and adaptation Journal of Systems and Software, 2011, 84, 185-197

[85] Kim, B.; Kim, T.; Ko, H.-G.; Lee, D.; Hyun, S. J. & Ko, I.-Y. Personal genie: a distributed framework for spontaneous interaction support with smart objects in a place Proceedings of the 7th International Conference on Ubiquitous Information Management and Communication, ACM, 2013, 97:1-97:10

[86] Klompmaker, F.; Busch, C.; Nebe, K.; Bleiker, A. & Willemsen, D. Fred, A.; Filipe, J. & Gamboa, H. (Eds.) Designing a Telemedical System for Cardiac Exercise Rehabilitation Biomedical Engineering Systems and Technologies, Springer Berlin Heidelberg, 2011, 111-122

[87] Helfert, M.; Raywalshe, null & Gurrin, C. The impact of information quality on quality of life: An information quality oriented framework IEICE Transactions on Communications, 2013, E96-B, 404-409

[88] Leahy, D. & Dolan, D. Holzinger, A. & Miesenberger, K. (Eds.) Digital Literacy Is It Necessary for eInclusion? HCI and Usability for e-Inclusion, Springer Berlin Heidelberg, 2009, 149-158

[89] Naranjo, J.-C.; Fernandez, C.; Sala, P.; Hellenschmidt, M. & Mercalli, F. Stephanidis, C. (Ed.) A Modelling Framework for Ambient Assisted Living Validation Universal Access in Human-Computer Interaction. Intelligent and Ubiquitous Interaction Environments, Springer Berlin Heidelberg, 2009, 228-237

[90] Rodrigues, G. N.; Alves, V.; Silveira, R. & Laranjeira, L. a. Dependability analysis in the Ambient Assisted Living Domain: An exploratory case study Journal of Systems and Software, 2012, 85, 112-131

[91] Ruiz-Lpez, T.; Noguera, M.; Rodrguez, M. J.; Garrido, J. L.; Chung, L.; Ruiz-Lopez, T.; Jose Rodriguez, M. & Luis Garrido, J. REUBI: A Requirements Engineering method for ubiquitous systems Science of Computer Programming, 2013, 78, 1895-1911

[92] Ruiz-Lpez, T.; Noguera, M.; Rodrguez Frtiz, M. J. & Garrido, J. L. Requirements Systematization through Pattern Application in Ubiquitous Systems Advances in Intelligent Systems and Computing, 2013, 219, 17-24

[93] Senart, A.; Cunningham, R.; Bouroche, M.; OConnor, N.; Reynolds, V. & Cahill, V. Meersman, R. & Tari, Z. (Eds.) MoCoA: Customisable Middleware for Context-Aware Mobile Applications On the Move to Meaningful Internet Systems 2006: CoopIS, DOA, GADA, and ODBASE, Springer Berlin Heidelberg, 2006, 1722-1738

[94] Storf, H.; Kleinberger, T.; Becker, M.; Schmitt, M.; Bomarius, F. & Prueckner, S. Tscheligi, M.; de Ruyter, B.; Markopoulus, P.; Wichert, R.; Mirlacher, T.; Meschterjakov, A. & Reitberger, W. (Eds.) An Event-Driven Approach to Activity Recognition in Ambient Assisted Living Ambient Intelligence, Springer Berlin Heidelberg, 2009, 123-132

[95] Ullberg, J.; Loutfi, A. & Pecora, F. Mazzeo, P. L.; Spagnolo, P. & Moeslund, T. B. (Eds.) Activity Monitoring by Multiple Distributed Sensing A Customizable Approach for Monitoring Activities of Elderly Users in Their Homes Springer, 2014, 13-25

[96] Walderhaug, S.; Mikalsen, M.; Salvi, D.; Svag rd, I.; Ausen, D. & Kofod-Petersen, A. Towards quality assurance of AAL services Studies in Health Technology and Informatics, 2012, 177, 296-303

[97] Walderhaug, S. l. Design and evaluation of the ModelHealth toolchain for continuity of care web services Automated Software Engineering, 2013, 20, 185-235

[98] Wienhofen, L. W. M.; Preuveneers, D.; Landmark, A. D.; Toussaint, P. J. & Berbers, Y. Beigl, M.; Christiansen, H.; Roth-Berghofer, T. R.; Kofod-Petersen, A.; Coventry, K. R. & Schmidtke, H. R. (Eds.) A Notion of Event Quality for Contextualized Planning and Decision Support Systems Modeling and Using Context, Springer Berlin Heidelberg, 2011, 307-320

[99] Wojciechowski, M.; Ristok, H.; Brandes, W.; Lange, B. & Baumgarten, G. Wichert, R. & Eberhardt, B. (Eds.) Architecture of the Daily Care Journal for the Support of Health Care Networks Ambient Assisted Living, Springer Berlin Heidelberg, 2011, 3-16

[100] Spanoudakis, N. & Moraitis, P. Weyns, D. & Gleizes, M.-P. (Eds.) Using ASEME Methodology for Model-Driven Agent Systems Development Agent-Oriented Software Engineering XI, Springer Berlin Heidelberg, 2011, 106-127

[101] OSGi Alliance. URL http://www.osgi.org/Main/HomePage. Accessed 2nd September 2014.

[102] Dimitrov, T. (2005). Design and implementation of a home automation service gateway based on OSGi. Master thesis, University of Duisburg- Essen, Dusseldorf, Germany.

[103] Thestrup, J., & Kostelnik, P. (2007). Networked Embedded System middle- ware for Heterogeneous physical devices in a distributed architecture. D2.2 Initial Technology Watch Report. Technical report, Hydra Consortium.

[104] Hydra Project. (2013). Hydra open source middleware. http://www.hydramiddleware.eu/. Accessed 20th May 2014.

[105] OASIS Project (2013). OASIS: quality of life for the elderly. http://www.oasis-project.eu/. Accessed 20th May 2014.

[106] OpenAAL. (2013). The open source middleware for ambient-assisted living. http://openaal.org/. Accessed 20th May 2014.

[107] Tazari, S., Valero, A. F., Dommarco, R., LazaroRamos, J. C., & Fur- fari, F. (2010). PERSONA PERceptive Spaces prOmoting iNdependent Aging. Final Reference Architecture model for AAL and recommendations for future activities on the Open AAL Platform. Technical Report D3.1.3, Fraunhofer IGD, ITACA UPV, and CNR-ISTI.

[108] Hanke, S., Mayer, C., Hoeftberger, O., Boos, H., Wichert, R., Tazari, M., Wolf, P., & Furfari, F. (2011). universAAL An Open and Consolidated AAL Platform. In Wichert, R., & Eberhardt, B. (Eds.), Ambient Assisted Living, (pp. 127140). Springer Berlin Heidelberg.