

A DSL-based Approach for the detection of Activities of Daily Living by means of the AGGIR variables

José Manuel Negrete Ramírez

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José Manuel Negrete Ramírez. A DSL-based Approach for the detection of Activities of Daily Living by means of the AGGIR variables. Other [cs.OH]. Université de Pau et des Pays de l'Adour, 2019. English. NNT : . tel-02437347

HAL Id: tel-02437347

https://univ-pau.hal.science/tel-02437347

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THÈSE

UNIVERSITÉ DE PAU ET DES PAYS DE L'ADOUR

École doctorale des sciences exactes et leurs applications

présentée et soutenue publiquement le `\ThesisDate`

par **José Manuel Negrete Ramírez**

pour l'obtention du
Doctorat de l'Université de Pau et des Pays de l'Adour
(mention Informatique)

A DSL-based Approach for the detection of Activities of Daily Living by means of the AGGIR variables

COMPOSITION DU JURY

Mise en page avec la classe thesuppa

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Composition du jury

Laboratoire Informatique de l'Université de Pau et des Pays de l'Adour
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Mise en page avec la classe thesuppa

Abstract

In recent years, the elderly population sector has increased faster than in the previous decades. In addition to that, elderly population suffers from age-related health issues and different chronic diseases. Furthermore, various studies indicate that the vast majority of elderly people are willing to live independently in their own homes as long as possible.

In order to assess the abovementioned problem, personal sensor networks and body sensor networks in smart environments represent an option regarding healthcare solutions for monitoring elderly people at home.

However, despite their popularity, the abscence of a monitoring approch with regard to a dependency evaluation model such as the AGGIR (Autonomie Grontologie Groupes Iso-Ressources) grid variables has never been treated.

Therefore, in this thesis work, with the aim of providing an analyis tool regarding the monitoring of ADL's performed by the elderly/handicapped people within a home environment by means of data recovered from sensors; a Domain Specific Language (DSL) relying on the AGGIR grid model is proposed.

The main contributions of this research work are:

- A state-of-the-art related to the proposed subject;
- A Domain Specic Language (DSL) for assessing the AGGIR grid variables;
- A framework for validating the proposed DSL.

For the purpose of determining the ADL's carried out by the elderly resident, as well as recognising the AGGIR grid variables; the introduced DSL is based on both temporal and location operators.

Moreover, with the goal to validate the abovementioned DSL, a framework architecture is presented in order to meet the requirements for analyzing complex events. To this extent, the framework is conformed by: (i) the DSL as its main component, (ii) the integration of the proposed DSL to a smart-home simulator for performing evaluation and experimentation; (iii) a parser aimed to process the data recovered from the DSL in order to generate appropriate instructions for the smart-home simulator.

KeyWords: Domain Specific Language, Feature-oriented Programming, Pervasive Computing, Pervasive Health Systems and Services, AGGIR grid

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Chapter 1

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In this chapter, a PhD thesis entitled *A DSL-based Approach for the detection of Activities of Daily Living by means of the AGGIR variables* is presented. Firstly, a description regarding the background and motivation concerning the thesis proposal is shown; emphasizing on the needs of the aging population as well as the application of pervasive computing technologies for solving health care within a smart home environment. Additionally, the scientific contributions of the proposed approach, as well as some possibles examples of their applications is explained. Moreover, an outline of the thesis work is introduced, in which the chapters included in the dissertation are indicated.

1.1 Background and Motivation

In this section, the problems aging population is facing in the nearest future are presented. That is, this population sector is aging more quickly than in the past; according to the United Nations Population Fund (UNFPA) projections. But not only that, elderly population suffers from age-related health issues and different chronic diseases. Several studies show that, at 90%, the vast majority of elderly people have the desire to live as long as possible, independently, in their own home [47]. For addressing the aforementioned issue, smart home environments have become an important research topic in recent years. It is possible to rely on the advantages that this tool can provide in the field of monitoring people at home.

According the United Nations Department of Economic and Social Affairs (UN DESA)[1], aging population is growing faster than ever before. Due to this increase, reducing medical costs and improving quality of care service have become in recent years a need for new care delivery mechanisms and structures [78, 182].

Personal Sensor Networks (PSN) and Body Sensor Networks (BSN) in smart environments have become a viable alternative to traditional healthcare solutions. PSN's are used to detect human daily activities, also known as Activities of Daily Living (ADL's), and measure conditions within the environment. BSN's are used to monitor vital signs and health conditions

[1] https://www.un.org/development/desa/publications/world-population-prospects-the-2017-revision.html

by measuring physiological parameters. Body sensor network systems can help people by providing healthcare services such as medical monitoring, memory enhancement, control of home appliances, medical data access, and communication in emergency situations [122, 167].

The MedicineNet.com Medical Dictionary defines Activity of Daily Living (ADL) as "the thing we normally do in daily living including any daily activity we perform for self-care (such as feeding ourselves, bathing, dressing, grooming), work, homemaking, and leisure". The evaluation for ADL's includes physical and mental skills. In the field of physical or occupational therapy, ADL reflects how well a disabled patient or individual recovering from a disease or an accident can function in daily life [31].

In order to provide a standardized way to estimate the physical well-being of elderly and their need for assisted living; a specific set of activities, called activities of daily living (ADL's), was first proposed by [82]. The activities included in this proposal conforming the set of ADL's are: bathing, dressing, toileting, transferring, continence and feeding. Moreover, another set of activities, called instrumental activities of daily living (IADL's), was studied in order to assess how well elderly interact with the physical and social environment by [98]. The set of IADL's comprise the following activities: using telephone, shopping, food preparation, housekeeping, doing laundry, transportation, taking medications and handling finances.

Additionally, innovative pervasive technology has been identified as a promising solution for facilitating the transformation of the current healthcare system from a hospital focused setting to a home centred setting [182]; and from managing illness to maintaining wellness.

Generally speaking, pervasive healthcare have been widely identified as a provider of promising solutions related to in-home healthcare services for the elderly people; mostly for those suffering from chronic illness, as well as for reducing long-term health care costs and improving the quality of care [9]. Nevertheless, the difficulty in developing pervasive applications lies in several aspects [59]:

1) Pervasive applications use many devices of various types. Considering the resource constraints of these devices, applications may need to address frequent failures due to energy or memory size limitations.

2) Sensor devices continuously collect a large amount of raw data about users and the environment. These raw data require efficient storage management and processing in order to provide meaningful context information for high-level applications. High-level reasoning must be able to process events with tolerance for inconsistent low-level events.

3) The applications need context information in order to provide a better user experience.

4) Pervasive applications need to adapt to the moving environment, which involves the maintenance of connections with devices and protocol adaptation for handling mobility.

Some previous works consisting on assisting elderly people to age in place while still having sufficient security standards in case of emergency are presented in [3, 33, 146].

In France, geriatricians use the AGGIR (Autonomy Gerontology Iso-Resources Groups grid, which is a scale, based on a ADL scale [43]. It is used to determine the dependency of the inhabitant; whether elderly people will need to be treated into a hospital, at a geriatric day care center, or similar; or have access to either financial support or material assistance to face dependency. the AGGIR grid, defines 10 discriminatory variables: coherence, orientation, toilet use, dressing, feeding, bowel movement, transfers (sitting, standing, lying), moving inside the flat, moving outside the flat, and communication (on the phone for example).

Several approaches propose different frameworks focusing on identifying the Activities of Daily Living (ADL's) that require monitoring [30, 75, 103, 110, 162, 170, 192]. However, there is still a lack of ADL activities to be analysed, whereas others consider a subset of specific activities; but most importantly, they are not based on a specific tool such as the AGGIR (Autonomy Gerontology Iso-Resources Groups) grid [43]. Moreover, the AGGIR grid is a well-established model, which allows to evaluate the autonomy degree of people in a very accurate way; by generating a score with test fidelity.

The aforementioned advantages and lacks have motivated this research for the development of:

- A Domain Specific Language (DSL) for the detection of ADL's according to the AGGIR grid variables.
- An approach to define, represent, manage, simulate, and detect complex activities regarding the AGGIR grid variables, based on time and location operators to relate single events or activities.
- A framework architecture integrating the aformentioned components for validating and evaluating the proposed DSL and the detection of single and complex activities related to the AGGIR grid variables.

1.2 Research overview and objectives

The AGGIR grid is an autonomy assessment tool used in France to measure the indenpendency level of elderly people [43]. It is a six-level dependence scale (GIR1 to GIR6), that can be defined based on a set of seventeen three-state variables. Each variable can have one of these values: **A**, for complete dependency; **B**, for partial dependency; and **C**, for complete independency.

The variables are classified into two groups: discriminatory and illustrative variables. Table 1.1 provides an overview for those variables previously mentioned.

Table 1.1: AGGIR variables

Discriminatory Variables	**Illustrative variables**
Coherence	Management
Location	Cooking
Toileting	Housekeeping
Dressing	Transportation
Self-feeding / Alimentation	Purchases
Elimination	Medical treatment
Transfers	Leisure activities
Indoor movement	
Outdoor movement	
Distant communication	

Context information is any information related to the use of characterization of the situation of any entity [2]. This latter could be a person, a place, a physical or abstract object, or an

event that is considered relevant to the interaction between a user and an application, including the user himself.

Due to the fact that a context-aware system needs to design the context information; important issues should be taken into account. Ones are considered internal, such as the system own awareness of current internal status and capabilities; and some others are external concerning to the real world, for example: place, time, user preferences and needs [90].

It is necessary to consider that the information which is part of a context may come from several sources, such as a sensor, a tablet or smartphone, etc.; and that those may also require different formats to represent the information they provide. There is a gap between sensor output and the abstraction level of the useful information for applications, and this gap may be bridged by various types of context information processing as explained by [67]. In addition, contextual information should be modeled at a high level of abstraction, near the user-level, preferring to mantain the ease of use, over the optimal efficiency, as indicated by [183].

"Context information is imperfect" and the system must assure information reliability and availability (as much as possible) [67]. Additionally, the user profile and the context history are also considered [70].

In order to propose health-related applications enabling elderly people to react, the application designer must be able to desing such application. A Domain-Specific Language (DSL) is an appropiate tool for this goal.

It is possible to rely on a DSL due to the fact that it is necessary express ADL's that respond to the fields of people with a physical or mental disability, support for elderly, diseases connected to aging. It is also indicated a need for a DSL, because this will now consider the integration of different types of context information: location, time and ADL's. The use of the proposed DSL will make possible to write textual specifications. The requirements for this latter are listed in Table 1.2.

Table 1.2: DSL Requirements

Context types	In order to be close to reality, the language should handle different types of context (i.e. location, time, event)
Ease of use	Easy and intuitive language in order to be used, so that users will be able to write / understand.
Model reuse	The language should allow the reuse of context models by different context-aware applications.
Independence from application domain	The language should allow the modelisation of contexts despite of the context application.
Model of independent platforms	Implementation details should not be carried out by the user.

In this context, a DSL that is able to categorise a set of activities based on the variables of the AGGIR grid [43] is introduced, which classifies autonomy levels to various environmental factors affecting the activities and social life of a person. In order to address such a task, a series of operators is defined, which deal with constraints related to time, location, and event recognition. Moreover, a framework is proposed that integrates the aforementioned DSL, alongside with a smart-home simulator called iCASA, by means of a parser capable of processing the data issued from the DSL; in order to create the adequate instructions for the iCASA

platform for performing the evaluation and experiments. That is, monitoring of the inhabitant within a smart home environment by identifying the activities performed by the elderly over a certain period of time, by means of collection and analysis of data obtained from sensors located within the smart home environment.

The proposed framework aims at providing an analysis tool regarding the performance of elderly / handicapped people within a home environment by means of data recovered from sensors using the iCASA simulator. In order to evaluate the proposed approach, the testability of the AGGIR variables and evaluate it their in many scenarios is studied, by means of records representing the occurrence of activities or unexpected behavior of the elderly.

1.3 Contributions

The contributions developed in this dissertation are enlisted in this section. That is,

- A state-of-the-art related to the subject proposed by this research work, regarding primarly studies on pervasive health care; as well as research concerning the categorization for the detection of activities of daily living.

- A DSL, based on the AGGIR grid evaluation model for evaluating the performance of ADL's of the elderly/handicapped at home; which is able to identify low level activities (e.g. posture and locomotion activities; which are possible to detect with just one sensor, a 3D-accelerometer or a smart phone) and high level activities (composed of a set of low-level activities) by incorporating operators for solving constraints related to time, space location and event detection.

- A tool for validating the proposed DSL; composed by: (i) the DSL as its main component, (ii) the incorporation of the DSL to a smart-home simulator called iCASA for performing the evaluation and experiments; (iii) the generation of a *parser* capable of processing the data issued from the DSL in order to create the adequate instructions for the iCASA platform;

- An use case description by experimentation carried out within the framework, where simulated smart home environment (iCASA) is integrated.

1.4 Publications

From the results of the contributions of this thesis, the following publications were produced and support the material presented in this work:

i) José M. Negrete R., P. Roose and M. Dalmau, "Distributed interfaces and context-oriented broadcast services in a smart-home environment," *2016 IEEE 12th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob)*, New York, NY, 2016, pp. 1-8.

ii) Negrete, José. M., Roose, Philippe, Dalmau, Mark, and Bakni, Michel (2018). Proposal and Validation of a Domaine Specific Language for the Representation of the AGGIR Constants. In *HEALTHINF* (pp. 438-445).

iii) J. M. Negrete Ramírez, P. Roose, M. Dalmau and Y. Cardinale, "An event detection framework for the representation of the AGGIR variables," *6th International Workshop on e-Health Pervasive Wireless Applications and Services 2018 (e-HPWAS'18)*, Limassol, 2018, pp. 153-160. (Best paper award)

1.5 Thesis Outline

This section is dedicated to present the remainder of the thesis; where the organization and the content of each chapter of the dissertation are described in a general manner.

The following chapters conformed this dissertation:

- Chapter 2 begins presenting a section dedicated to related studies on Pervasive Healthcare Evolution. Then, a section describing related studies on the categorization for the detection of ADL's, is presented. In addition, technologies regarding the maintenance and monitoring of individuals at home, are identified. Moreover, an overview of evaluation models on the extent of performance of ADL's is presented.

- Chapter 3 introduces the proposed DSL; which incorporates operators in order to deal with time and location of complex activities (activities composed by a set of simple activities) and event detection constraints. The proposed DSL is intended to describe activities performed by elderly/handicapped subject within a smart home environment and to identify the AGGIR grid variables. Additionally, an overview of the existing works that serve as a background for the proposed approach are provided. Then, the orchestration for the detection of activities of daily living according to the AGGIR grid variables is presented.

- Chapter 4 proposes an architecture for a framework to study the AGGIR grid model, in order to evaluate the level of independency of elderly people, according to their capabilities of performing activities and interact with their environments over the time. Next, all the main components of the framework are described briefly in this chapter.

- Chapter 5 presents experiments to evaluate the performance of the DSL, proposed in Chapter 3. Also, a review of the state of the art regarding technologies under use, is presented. Afterwards, it is presented the methodology for a case study concerning ADL's detection, to highlight the benefits and limitations of the thesis proposal, in order to follow elderly at home. The framework aims at providing an analysis tool regarding the performance of elderly/handicapped people within a home environment by means of data recovered from sensors within a smart home simulator. Moreover, experimentation was carried out and results were analyzed after simulation.

- Chapter 6 summarizes and concludes all the contributions of this thesis work and provides an overview of future development of the work that will follow this research.

Chapter 2

Healthcare and Human Monitoring Activities

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This chapter begins with a section dedicated to related studies on Pervasive Healthcare Evolution. Next, a section describing related studies on the categorization for the detection of Activities of Daily Living (ADL's), is presented. In addition, we identify the technologies regarding the maintenance and monitoring of individuals at home. Moreover, we present an overview of evaluation models on the extent of performance of activities of daily living at home.

2.1 Pervasive Healthcare Evolution

In this section, the information that serves as a background for the motivation of this thesis work is reviewed. Firstly, recent studies regarding the future circumstances of an aging population, globally speaking, are described. Secondly, a review concerning the potential of technology assisting people in maintaining and monitoring their own health, is given.

2.1.1 Aging Society

According the United Nations Department of Economic and Social Affairs (UNDESA), population is aging faster than ever before. Since 1950-1955, life expectancy at birth has risen by more than 10 years in Northern America, Europe and Oceania, and by close to 25 years in Latin America and the Caribbean; as shown on Figure 2.1. Due to this increase, reducing medical costs and improving quality of care service have become in recent years a need for new care delivery mechanisms and structures. The increasing of elderly population worldwide brings a need for more healthcare options. Both in Europe and the U.S.A, there is a sense of urgency since growing numbers of care dependent older persons with chronic conditions are served in the community, along with a reduction in the primary care workforce, and reductions or changes in public health care budgets [20, 78, 91, 152, 180]. Figure 2.2 and Figure 2.3 provide information on the trends about destination of public resources in the long-term care field. It indicates a large public expenditure is spent on inpatient long-term care (LTC) in most countries. Thus, traditional healthcare systems will not be sufficient with the actual demands. Then, there exists a need to establish a different way of providing healthcare for a growing population of elderly while reducing healthcare costs.

To this extent, technologies for maintaining and monitoring the health of individuals at home represent a relevant tool regarding this subject. Next section is focused in that aspect.

The increasing elderly population worldwide brings a need for more healthcare options. Both in Europe and the U.S.; there is a sense of urgency since growing numbers of care dependent older persons with chronic conditions are served in the community, along with a reduction in the primary care workforce, and reductions or changes in public health care budgets [20, 78, 91, 152, 180]. Additionally, since 1950-1955, life expectancy at birth has risen by more than 10 years in Northern America, Europe and Oceania, and by close to 25 years in Latin America and the Caribbean; as shown on Figure 2.1. Also, Figures 2.2 and 2.3 provide information on the trends about destination of public resources in the long-term care field. It indicates a large public expenditure is spent on inpatient long-term care in most countries. So, traditional healthcare systems will not be sufficient with the actual demands. Then, there exists a need to establish a different way of providing healthcare for a growing population of elderly while reducing healthcare costs.

2.1.2 Promising Use of Technology

Advanced sensing and communication technologies have started to come together, which provides the opportunity for health care solutions that may become both ambient and pervasive. Some of these technologies, presented in this section, are focused on the field of health care at home. Next section describes several categorization of activities that, in addition to technologies, will help to articulate assisting and monitoring of people at home in a more efficient manner.

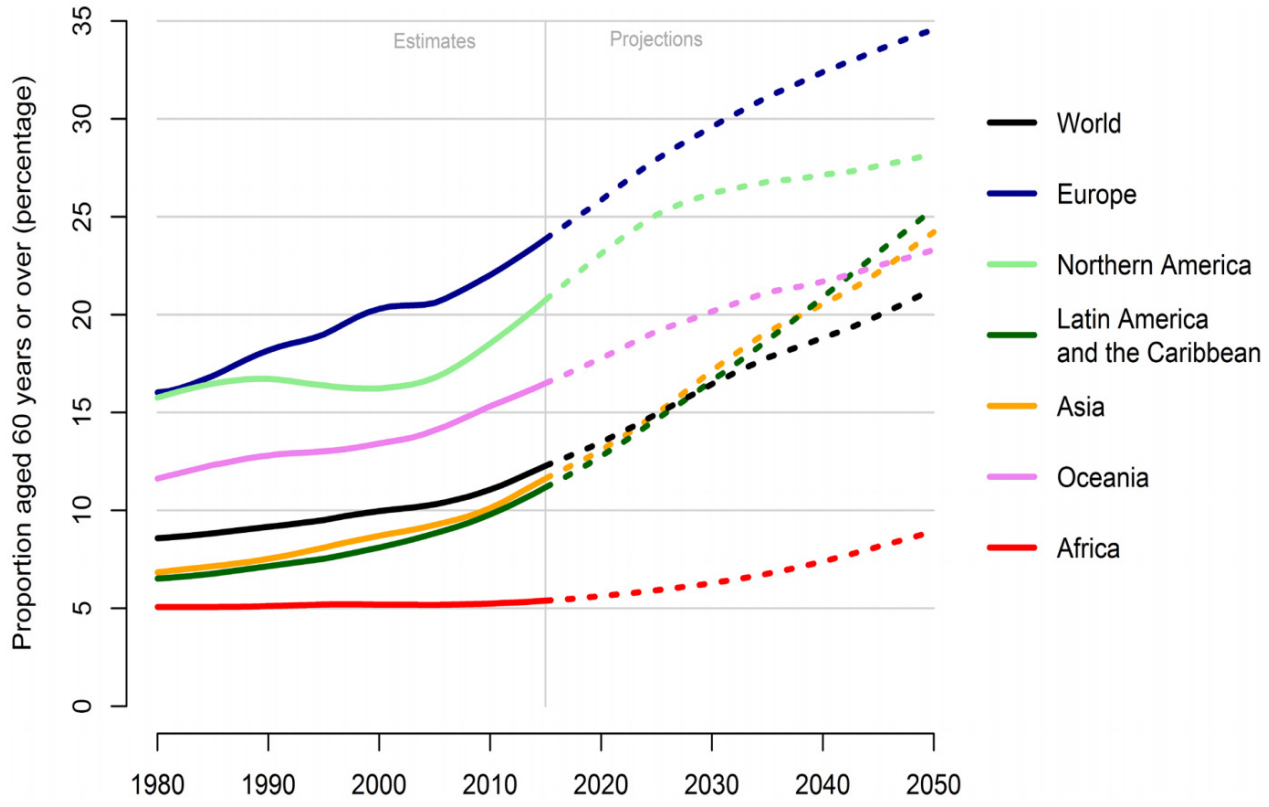


Figure 2.1: Life expectancy at birth by region, both sexes combined, from 1950 to 2050. *Data source*: United Nations (2017). World Population Prospects: the 2017 Revision.

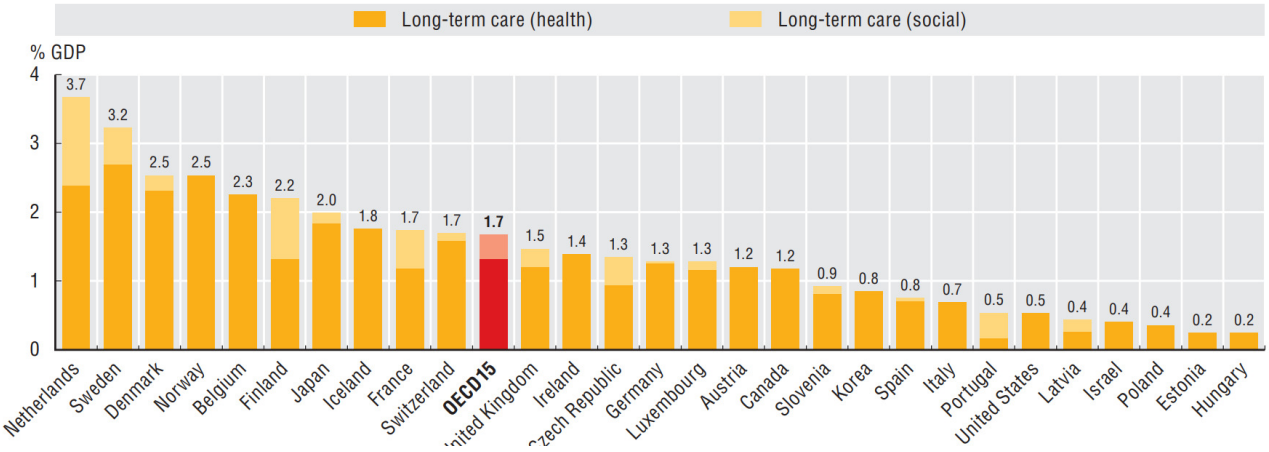


Figure 2.2: Long-term care expenditure (health and social components) by government and compulsory insurance schemes, as a share of GDP (Gross Domestic Product), 2015 (or nearest year) [130].

The evolving concepts of pervasive computing, ubiquitous computing and ambient intelligence are increasingly influencing health care and medicine [132]. Pervasive computing is associated with the development of mobile or embedded information and communication technologies (ICT) with network connectivity, and advanced user interfaces [5, 113, 157, 159]. Pervasive computing helps to improve traditional health care because of its ubiquitous and unobtrusive analytical, diagnostic, supportive, and information functions [119, 187].

The opportunity for healthcare solutions that may become both ambient and pervasive

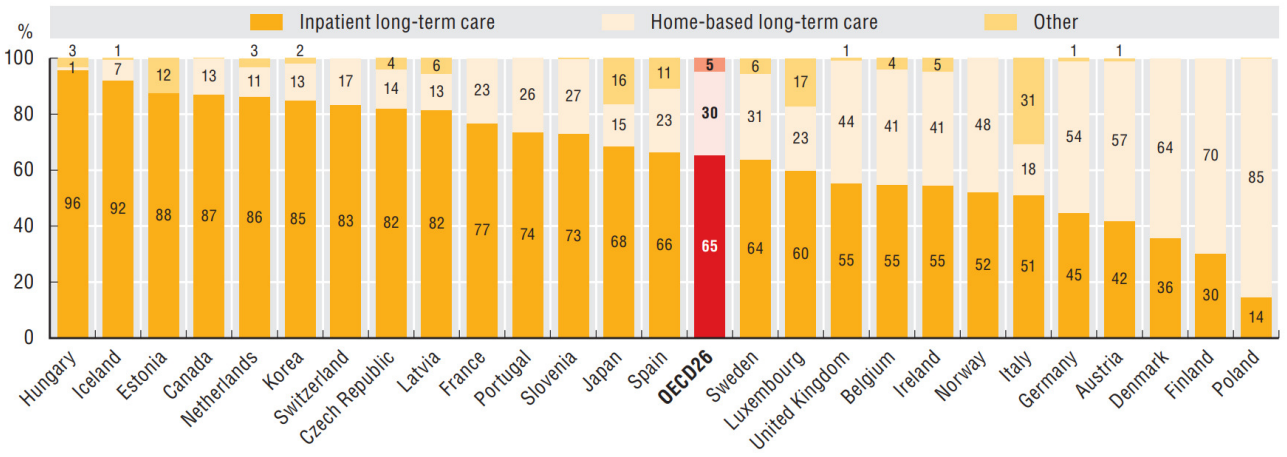


Figure 2.3: Government and compulsory insurance spending on LTC (Long-Term Care) health by mode of provision, 2015 (or nearest year) [130]

is possible thanks to the convergence of advanced sensing and communication technologies [21]. Moreover, technology can support the network of caregivers such as family members, and clinicians by providing new and innovative tools to monitor the well-being of elder people, by enabling a rapid response to emergency situations [39]. Also, it has been considered that at-home healthcare systems will allow people to monitor themselves with devices that provide warnings of illness; so that they can ask for medical help earlier, when intervention can be the most effective; helping to overcome many challenges, especially in acceptance and usability for the ageing population [65, 121].

2.2 Human Monitoring Activities: State of the Art

In addition to pervasive health care, activities performed by the subject are relevant for our work. For this matter we review categorization of activities proposed in related literature, focusing on low-level activities (Section 2.2.1), high-level activities (Section 2.2.2), and ADL's (Section 2.2.3).

2.2.1 Low-Level Activities

Low-level activities consists on activities that can be detected with the use of one sensor (i.e., sitting, lying, standing, moving, rolling). Research regarding the monitoring and recognition of low-level activities has been well conducted in recent years. It has been demonstrated that reliable detection of a few activities (e.g., posture and locomotion activities) is possible with just one sensor, a 3D-accelerometer, or a smart phone [45, 100, 109, 134]. As an example, a tri-axial accelerometer is used to create a real-time personal life log system, based on activity classification: lying, sitting, standing, walking, going upstairs, going downstairs and driving [101]. Next, works on recognition of low-level activities with just one are presented. Acceleration data were obtained from wireless motion bands which send 3D raw acceleration signals via a Bluetooth link to a PDA, which then performs the data collection, feature extraction and activity classification [45]. A method to convenient monitoring of detailed ambulatory movements in daily life is presented in [100], by the use of a portable measurement device employing single tri-axial accelerometer. A single tri-axial accelerometer placed on the waist was used to record the acceleration data for human physical activity classification in [109]. Methods for

automatic activity classification from data collected with body-worn sensors are described in [134]; by taking a data-oriented and empirical approach and collecting a large data library of realistic data.

Studies regarding the recognition of low-level activities by means of embedded sensors in a smart-phone have been proposed. Detection of activities such as: walking, jogging, going upstairs, going downstairs, sitting and standing is proposed by [94]. On the other hand, both the position and the orientation of the device is not determined during regular usage, which has to be considered during recognition of activities, as explained by [17], where reasoning techniques models were applied in an online learning setting to perform classification of personalizable movement activities using phone accelerometer data and some user feedback. Additionally, the efficiency of energy for such devices plays an important role; for this matter, research have been conducted concerning energy-efficient solutions on mobile phones, such as: a proposal a sensors selection method for activity recognition which leverages the predictability of human behaviour to conserve energy [55]; and also for reducing the energy overhead of continuous activity sensing, the choice of accelerometer sampling frequency and classification features were investigated in order to recognise how this affects, separately, the "energy overhead" vs. "classification accuracy" tradeoff for each activity [188]. Furthermore, recognition of low-level activities with multiple sensors are proposed in [8]; whose results of a comparative study where features extracted from miniature inertial and magnetometer signals are used for classifying human activities; and [135], where a set of different classification techniques and factors that affect classification performance for activity recognition based on accelerometer data is presented.

2.2.2 High-Level Activities

High-level activities are composed of a set of low-level activities. Moreover, those activities usually last longer than low-level activities (i.e., they can last up to a few hours). With the knowledge obtained about an individual high-level activities, the recognition of his low-level activities can be improved. For example, if the recognized high-level activity is *shopping*, during this time the probability of the activity *walking* is much higher than *running*. Or if the recognized high-level activity is *Pre-Hypertension*, for this health issue; the probability of high *Systolic Blood Pressure* and *Diastolic Blood Pressure* will be present. Although the recognition of high-level activities is important for the description of an individuals daily routine, research has so far mainly focused on low-level activities.

A study regarding a realistic dataset, including three high-level activities: preparing for work, going shopping and doing housework, is presented in [74]. Each of these activities is composed of a set of low-level activities. For example going shopping consists of: driving car, walking, working at computer, waiting in line in a shop and strolling through a shop. The importance of this approach relies on how the recognition of low-level activities can be utilized for high-level activity recognition; by means of the same algorithms as the recognition of low-level activities.

Additionally, a work recognizing a large set of low-level activities using a wearable sensor platform is described in [73]. By using this data, they achieved modeling and recognition of daily routines without user annotation. Overall, four daily routines (high-level activities) were recognized: commuting, office work, lunch routine, and dinner activities.

Finally, another research works regarding the analysis of composite activities as a set of recognized low-level activities are overviwed in other works: a set of sensors is configured at a semantic level available at any point in time according to needed reasoning techniques, is proposed by [69]. Additionnally, a large recording of twelve subjects performing morning

activities (ADL's), using numerous sensors on the body and in the environment is described in [111]; and a recorded of a set of ADL's in a sensor rich environment using seventy two environmental and body sensors is presented in [153].

2.2.3 Activities of Daily Living

ADL's represent a set of activities that the subject carries out as part of his normal daily schedule. The ADL's concept was first proposed in [82], in order to provide a standardized way to estimate the physical well-being of elderly and their need for assisted living. The activities included in this proposal conforming the set of ADL's are: bathing, dressing, toileting, transferring, continence, and feeding. In addition, another set of activities, called instrumental activities of daily living (IADL's), was studied in order to assess how well elderly interact with the physical and social environment [98]. The set of IADL's comprise the following activities: using telephone, shopping, food preparation, housekeeping, doing laundry, transportation, taking medications, and handling finances.

Several works regarding the monitoring and recognition of specific subsets of ADL's/IADL's have been proposed. For example, a combination of RFID tags and accelerometers in order to recognize 10 housekeeping activities (such as dusting or vacuum cleaning) [169]. Their approach considers: *1)* the objects people use during the execution of an activity to determine that activity by means of RFID tags; and *2)* the activity defined by body movements during its execution, with the use of accelerometers. Moreover, 15 ADL's were distiguished by a wrist-worn device which includes sensors: accelerometer, microphone, camera, illuminometer and digital compass. The results issued from experimentation showed that the camera is the most important single sensor in the detection of this subset of ADLs, followed by the accelerometer and the microphone [115].

Further examples on the topic of monitoring and detecting ADL's/IADL's are presented in [29, 114, 148, 181, 189]; as presented on Table 2.1.

2.2.4 Activity Monitoring

Recognition of Activities of Daily Living

Activity recognition is a well-known process in health monitroring systems and is one of the most promising research topics for context aware computing and ambient assisted living. It aims to detect or recognize human activity and behaviour patterns in real-life settings [87]. Assisted living systems for subjects like the elderly aim to monitor and evaluate the subject's health condition and their abilities to carry out daily activities by: (*i*) recognizing concurrent activities: performing several activities at the same time; (*ii*) recognizing interleaved activities: activities that are overlapped with others in real life; (*iii*) ambiguity of interpretation: similar actions may be interpreted differently based on the context; and (*iii*) support of multiple residents: recognize the activities performed in parallel by the occupants in a group [103].

Advances in ubiquitous and pervasive computing have resulted in the development of a number of sensing technologies for collecting information related to human daily activities. Different approaches for ADL monitoring have been proposed using different sensing mechanisms [30, 75, 103, 110, 162, 170, 192]; as shown on Table 2.2.

The environmental sensor-based approach has received significant attention in recent years. Personal Sensor Networks (PSN's) or environmental sensors are in charge of colleting data concerning the individual and their environment. PSN's can be placed within the living environment or attached to several objects at home in order to detect the inhabitant's activity.

Table 2.1: Works concerning monitoring and detection of ADL's/IADL's

Work	**Target**	**Description**
[29]	Elderly population	The use of location in recognising ADL's is investigated, either by bringing location in the feature level, or by utilizing it to filter irrelevant sensor readings.
[114]	General population	In this work a battery-shaped sensor node is implemented to monitor the use of an electrical device into which it is inserted bysensing the electrical current passing through the device. Also, a method is proposed to identify into which electrical device the sensor node is inserted and recognizes electrical events related to the device by analyzing the current sensor data.
[148]	General population	A competitive approach developed for an activity recognition challenge is described. The competition was defined on a dataset of human activities, recorded with smartphone sensors. This work investigates different feature sets for the ADL's recognition task of the competition.
[181]	General population	A hierarchical structure is presented in which it is assumed that each activity consists of a number of actions, in order to model the ADL's from sensor data.
[189]	General population	A wearable acoustic sensor, called BodyScope, is developped to record the sounds produced in the bubject's throat area and classify them into user activities, such as eating, drinking, speaking, laughing, and coughing.

Table 2.2: Approaches regarding ADL's monitoring

Work	**Target**	**Description**
[30]	Elderly population	An activity recognition and classification method for detection of ADL's of an elderly person using small, low-cost, non-intrusive non-stigmatize wrist worn sensors is presented: for a practical assisted living system in term of user acceptance, privacy (non-visual) and cost.
[75]	Elderly population	Context-Aware Service Integration System (CASIS), an event-driven service-oriented system framework integrating web services and OSGi platform; is introduced. It provides context-aware healthcare services to the elderly resident in the intelligent space, allowing remote caretakers to monitor and attend to the elder's physical and mental well-beings
[103]	Elderly population	The Smart Auto-Dep framework is proposed to evaluate a subject's dependency, based on the ADL's defined by the AGGIR scale [43]. It proposes a context-aware monitoring and evaluation for assessing the dependency level of the elderly; in order to guarantee an appropriate level of monitoring and services. The use of IP cameras and sound detectors for their identification makes it intrusive. We believe our approach can provide many of the same benefits without intruding into the living space.
[110]	General population	Identification of ADL's by means of wireless sensor networks, radio frequency identification devices (RFID), machine learning.
[162]	Elderly population	This work proposes estimation of basic ADL's using amotion recognition method based on 3D acceleration sensors and ZigBee networks. Tagging technology is used to recognize what area of a house the individual is in and then apply accelerometer-based information for classification.
[170]	Elderly population	A mechanism for estimation of elderly well-being condition based on usage of house-hold appliances connected through various sensing units, is presented. Two wellness functions are defined to determine the status of the elderly on performing essential ADL's.
[192]	Elderly population	The Context Aware Real-time Assistant (CARA), a context-aware hybrid reasoning framework that integrates fuzzy rule-based reasoning with Case-Based Reasoning (CBR) for pervasive healthcare in smart home environments is presented. It processes information uncertainty and uses context to provide context-aware sensor data fusion as well as anomaly detection mechanisms for ADL's analysis and alert generation.

For instance, Passive infrared (PIR) sensors are most frequently used for detecting the person's presence [49] and ADL's [129]. Additional sensors such as motion sensors, door contact sensors, pressure sensors, object RFID tags, and video cameras are required for gathering activity related information [174]. RFID is used to identify users and objects in a smart environment [72]. Pressure [75] and ultrasonic sensors [71] can be attached to home objects to track their locations and therefore the movements of the user. Moreover, the usage of electrical appliances such as microwaves, water kettles, toasters, room heaters, and televisions can also be used to detect activity and to further refine behaviour information [171].

In addition, Body Sensor Networks (BSN's), which rely on wearable sensors have proved to be an effective method for human activity recognition. They are small in size, lightweight, low cost, and non-invasive. BSN's use wearable sensors carried by monitored subjects such as the elderly and patients. These sensors provide a continuous flow of information about real-time health conditions; such as heart rate, oxygen saturation, blood pressure, blood glucose, body temperature and weight. Wearable sensors have been embedded into watches [16, 80], shirts [102], belts [79], etc. Existing approaches regarding activity recognition based on multiple accelerometers placed on different body parts are proposed in [92, 147, 173]. Furthermore, a research focusing on activity recognition by means of accelerometers, temperature sensors and microphones to analyze multiple time domain feature sets is proposed in [120].

Another field used as an alternative platform for activity recognition is the smartphone; which does not require any additional equipment for data collecting or processing. Recent research regarding the use of this device as a platform for mobile sensing and computing for detecting activity recognition are presented in [38, 86, 94].

2.2.5 Context Awareness and Context Reasoning Healthcare

The context plays a primordial role during health monitoring in a smart environment, due to the fact that evaluating the monitored subjects regarding their health conditions and their performances in accomplishing their ADL's, relies mainly on the comprehension of the sensed context of subjects. This section provides a brief state of the art concerning the concepts of context awareness and context reasoning, which represent a valuable knowledge for healthcare systems in order to provide reliable context-aware services. Additionally, they must rely on the dependency evaluation models for the elderly; which are revised in section 2.3.

Context-aware Healthcare

Context-aware computing has the potential to make a significant impact upon everyday human life by building an environment that is capable of recognizing and responding to the presence of individuals in a seamless and unobtrusive way [42]. Additionally, for altering the relationship between humans and technology, it is essential for systems that aim at helping people in their daily life to be context-aware [118]. Context awareness is also one of the primary characteristics of smart homes. Many research smart home labs have been built as test beds for context-aware pervasive computing [192].

This area has attracted a vast amount of research, and some prototype systems have already been developed [4, 35, 63, 145, 155]. Some recurring aspects of works considering the integration of the smart home technology with the healthcare system are as follows: (*i*) for automating the activation/deactivation of some devices depending on the user needs [34, 62, 196]; (*ii*) for understanding the usual behaviour of the user so that caregivers can supervise and assess the pattern of behaviour and detect anomalies [138]; (*iii*) for increasing safety and saving energy [84, 106, 125, 151, 195, 197].

Basically, the smart environment should learn how to react to the actions and needs of the user, and this should be achieved in an unobtrusive and transparent way [13]. Furthermore, learning means that the environment has to gain knowledge about the preferences, needs, and habits of the user in order to better assist the user [53, 99]. Moreover, it is insufficient to learn user patterns only once because preferences and routines can change with time. Hence, it is necessary for a smart home environment to adapt itself to these new patterns continuously [156].

Context Reasoning

Reasoning techniques to achieve context awareness has been previously proposed [112, 144, 186]. There exist a large number of different context reasoning decision models. Most of these models are employed in the fields of artificial intelligence and machine learning; and generally used across many different fields in computing and engineering. The context reasoning component is usually developed to understand the user behaviour, or to make high-level decisions, when combined with other types of knowledge.

A state-of-the-art regarding context reasoning for elderly based on ambient intelligence is surveyed in [18, 146]. Most context reasoning techniques in pervasive healthcare are related to Artificial Neural Networks, Statistical Classification, Case-based Reasoning, and Fuzzy Logic;

Artificial Neural Networks: In [27], it is proposed one of the first reports of an application using Artificial Neural Networks (ANNs) for smart home environments in which the user behavior patterns were considered.

The aim of this system was to design an adaptive house that considers the lifestyle of the inhabitants to achieve home automation. For this matter, they relied on a feed-forward neural network to determine if a given situation was normal or abnormal. After applying their approach in an institution for elderly and disabled people, they validated that 90% of predictions made by the system were correct. A proposal of an adaptive smart home system for optimal utilization of power, through ANN was provided in [14]. The aforementioned system consists of a recurrent neural network to capture human behavior patterns and a feed forward architecture in ANN for security applications in smart home environments.

However, there are some limitations of using ANNs regarding their "black box" nature, because they provide little explanatory insight into the relative influence of the independent variables in the prediction process [131]. In other words, their internal structure is not human-readable; not making it able to explain how it inferred a particular result.

Statistical Classification: Another approach for identification to which set of categories a new observation belongs, considered as an instance of supervised learning is statistical classification. It aasumes that a training set of correctly identified observations is available. For that, a classifier is defined as an algorithm that implements classification. It uses a training set to create a statistical model according to a mathematical function that is able of mapping input data to a category. Typical classifiers include: Bayesian Networks, Hidden Markov Models, Decision Trees, and Support Vector Machines. The aforementioned methods have been widely used for mobile phone sensing [97] and activity recognition [150].

According to [23], "a user is only willing to accept an intelligent environment offering services implicitly if he understands and foresees its decisions" .Moreover, it was identified that the model generated by decision trees is easy to understand and suitable for human inspection [168]. In this work, it was proposed the use of a decision tree classifier with collected data

describing the order to detect abnormal situations. As a result, any situation considered as external to the decision tree would be identified as abnormal. Nevertheless, a system built upon such a hypothesis can generate some false alarms, because new situations outside the environments are not always abnormal.

Case-based Reasoning: The principle of Case-based Reasoning (CBR) is to recover former, already solved problems similar to the current one and to attempt to modify their solutions to fit the current problem [1]. Also, CBR can be defined as an instance-based learning technique, in order to learn the preferences of the user [93]. Additionally, the system proposed in [93], recorded the set of tasks that the user usually performed, and tried to provide information to the user by means of a CBR module that matched cases using a K-nearest neighbor algorithm. In [28], a CBR-based expert system was developed by designing a flexible auto-set tolerance (T), which serves as a threshold to extract cases for which similarities are greater than the assigned value of T, to help doctors diagnose complex diseases particularly those that involve multiple domains in medicine.

Nevertheless, instance-based learning techniques infer a solution for each instance, instead of creating a model that represents patterns. Therefore, it is not possible to obtain a general pattern describing the behaviour of users. Furthermore, it is necessary to provide an important number of cases to have significnt results; making the matching process complicated because there are no clues concerning the importance of each parameter for each case [154].

Fuzzy Logic: The aim of fuzzy logic formalize the "approximate reasoning" used in everyday life. It is strictly related with multivalued logic where truth values besides 0 (false) and 1 (true) are allowed [19, 54, 137, 193, 194]. It provides a simple way to reach a definitive conclusion based upon ambiguous or imprecise information which is relevant in context information processing. In addition, knowledge is defined by fuzzy sets and fuzzy rules [172], which are considered more robust when dealing with data of a continuous nature; allowing the use of natural language (e.g., body temperature: slightly warm, fairly cold) .

A work relying on an application that generated a set of fuzzy rules representing habits of the user in the smart home environment is presented in [177]; by manually developing the membership functions that mapped data into fuzzy sets, and made inference on fuzzy sets according to fuzzy rules. Several examples of applying fuzzy logic to represent context information are presented in [133].

However, the fact is that the ”knowledge acquisition bottleneck” still remains one of the key problems in the design of intelligent and knowledge-based systems. Indeed, experience has shown that a purely knowledge-driven approach, which aims at representing problems related human expert knowledge, is often difficult and tedious [191].

2.3 Dependency Evaluation Models

After reviewing concepts concerning ADL's and pervasive health care, it is important to highlight the most commonly used measurement models in the domain of health and dependency evaluations. For this matter, following sections present different tools and methods which include the determination of a basic ADL and the methodology of assessment to evaluate each activity.

2.3.1 Katz Index of ADL's

The Katz index of ADL's was developed to address the functional status as a measurement of the ability of the elderly to perform ADL's independently [82, 83]. The Katz index includes six items describing ADL's ordered by dificulty: (a) bathing; (b) dressing; (c) toileting; (d) transfer; (e) continence; and (f) feeding. In order to evaluate the independence of the elderly, scores regarding yes/no are given to each item; using 1 point scale of independence and 0 point for dependence. The total score value indicates the level of dependence: (i) 6 indicates full function; (ii) 4 indicates moderate impairment; and (iii) 2 or less implies severe functional impairment.

2.3.2 The Lawton-Brody Instrumental Scale

The Lawton Instrumental Scale represents a tool to assess the Instrumental ADL's (IADL's) such as: (a) ability to use telephone; (b) shopping; (c) food preparation; (d) housekeeping; (e) laundry; (f) mode of transportation; (g) responsibility for own medications; (h) ability to handle finances [98].

Eight items are measured within the Lawton scale, represented by 0 for dependency and 1 for independency. Women are evaluated on all the eight areas of functions, whereas for men, food preparation, housekeeping, and laundry are excluded. For women, a score ranges from 0 (low function or dependent) to 8 (high function or independent). For men, the score ranges from 0 through 5 [58, 98]. Moreover, elderly are evaluated according to their highest level of functioning.

2.3.3 Barthel Index of Activities of Daily Living

The Barthel index (BI) of ADLs measures the functional disability by proposing a quantification of the patient performance concerning 10 ADL's [116].

The BI can be used to determine the level of functioning of the patient and can be employed for monitoring the improvements achieved in the performance of activities over time. In addition, the BI is widely used in rehabilitation. Also, the 10 evaluated activities comprise scores by means of the values 0, 5, 10, or 15 depending on each item: 0 for unable, 5 for requiring help, 10 or 15 for independent. The values are summed up to generate a total score varying from 0, which represents a totally dependent person; to the maximum score of 100, indicating that a patient is fully independent. These scores are divided into four groups [37]: (i) <20: for a total dependence; (ii) 20-40: for a severe dependence; (iii) 40-60: for a moderate dependence; (iv) >60: for a mild dependence.

2.3.4 Functional Independence Measure

The functional independence measure (FIM) score system was developed to suit rehabilitation aspects of patients with disabilities. It is based on the conceptual framework of pathology, impairment, disability, handicap, and burden of care [85]. The FIM consists of 18 separate items and is divided into six sections: self-care, sphincter control, mobility (transfers), locomotion, communication, and social cognition (including social integration, problem solving, and memory). Items are classified into two main domains: motor (13 items) and cognitive (5 items). Each item is separately graded according to a 7-point scale: 1 for total assistance, 2 for maximal assistance, 3 for moderate assistance, 4 for minimal contact assistance, 5 for supervision, 6 for modified independence, and 7 for complete independence. The range for FIM is from 18

(dependent) to 126 (fully independent). Moreover, scores are categorized into three groups: (*i*) requiring assistance comprising the scores from 1 to 4; (*ii*) requiring supervision (score 5); and (*iii*) requiring no help with the scores of 6 and 7 [68].

2.3.5 Northwick Park Dependency Score

The Northwick Park Dependency Score (NPDS), is applied for the assessment of the requirement of nursing time in a rehabilitation setting in order to evaluate the full range of dependency [176]. Additionally, The NPDS is used in the UK and has been established in other countries [164].

The NPDS is divided into two sections: basic care needs (BCN) and special nursing needs (SNN). The BCN section (with a score range from 0 to 65) includes 16 items within 5 subscales, including the daily activities required for everyday living. Each item is rated on a scale either from 0 to 3, 0 to 4, or 0 to 5. These items enlist the capacity for performing both ADL and cognitive behavior.

The SNN section (with a score range from 0 to 35) includes 7 care items indicating the need for nursing care. These items are scored on a rate scale of 0 or 5 to remark the importance of nursing that they consider. Moreover, the total scores from each section summarize the total composite NPDS score, ranging from 0 to 100 (65 for BCN and 35 for SNN). Lower scores will demonstrate that the person possesses more independency. The dependency level of NPDS is categorized into three groups: Low, Medium, and High [175]. In low dependency (<10), patients are largely self-caring and barely require help with ADL. In the medium dependency category (between 10 and 25), patients require human help for performing most of their ADL tasks. In the high dependence category (>25), patients require human help provided by two or more people for performing most of their ADL tasks, and often require special nursing needs.

The items considered into the Northwick Park Dependency Score are enlisted on Table 2.3.

Table 2.3: Northwick Park Dependency Score [176]

BCN items
Mobility
Transfers
Toilet / bladder
Urinary incontinence
Toilet / bowels
Faecal incontinence
Washing / grooming
Bath / shower
Dressing
Eating
Drinking
Skin care
Safety awareness
Communication
Behaviour

SNN items
Tracheostomy
Gastrostomy
Pressure sore
>2 interventions/night
Psychological support
MRSA (multiply resistant Staphylococcus aureus) positive
Acute intervention
Wanderer

2.3.6 The Functional Autonomy Measurement System (SMAF) model

The Functional Autonomy Measurement System (SMAF) is a clinical rating scale used in Canada that measures the functional autonomy of elderly patients [61]. For this scale, the handicap is the relation between disability and the available social or material resources, taken into account to alleviate the rate of disability. The SMAF model is used to rehabilitate individuals by providing them appropriate care, services, and assessing needs to alleviate the disabilities of elderly people. It consists of a 29-items rating scale used to evaluate the dependency of the person and access to available resources devoted to disabilities as well the stability of resources. These items are included in the following five aspects of functional abilities: (*i*) activities of daily living (7 items); (*ii*) mobility (6 items); (*iii*) communication (3 items); (*iv*) mental functions (5 items); and (*v*) IADL (8 items). The SMAF model is administrated manually by a health professional. The dependency is evaluated by using a 5-point rating scale for each item: *0*, *-0.5*, *-1*, *-2*, and *-3*. Such items are evaluated using a function scoring with: (*a*) *0*: independently; (*b*) *-0.5*: independently but with dificulty; (*c*) *-1*: needs supervision or stimulation; (*d*) *-2*: needs help; and (*e*) *-3*: dependent. Ten of the SMAF items are measured only by using a 4-point rating scale (i.e., *0*, *-1*, *-2*, and *-3*) such as Urinary, Bowel, and Vision.

The SMAF model has been proposed by [41], and it includes 14 profiles of dependency patterns called iso-SMAF profiles. Based on the disabilities of groups, each profile is associated with a specific amount of support of services, nursing, costs of services, and need of supervision. In the SMAF model, the first profile (profile 1) represents the persons who are autonomous while the last profile (profile 14) represents completely dependent persons.

These profiles are defined based on the results of the information of all the 29 items. The 14 iso-SMAF profiles are separated into 4 broad categories: (*i*) mild mainly IADL disabilities: includes subjects who are autonomous with some IADL required supervision and help (comprising profiles 1, 2, and 3); (*ii*) intermediate predominantly motor disabilities: includes subjects who show mobility functions disabilities (comprising profiles 4, 6, and 9); (*iii*) intermediate predominantly mental disabilities: includes subjects who show mental disabilities (comprising profiles 5, 7, 8, and 10); and (*iv*) severe and mixed disabilities: shows the lowest level of autonomy in all the ADL activities (comprising profiles 11, 12, 13, and 14) [41] [141]. Figure 2.4 describes each profile as it presented in [141].

2.3.7 The Autonomy Gerontology Iso-Resources Groups (AGGIR) grid model

A similar tool to the SMAF model is the AGGIR grid. The AGGIR grid is an autonomy assessment tool used in France to measure the independency level of elderly people. it consists on seventeen variables which describe either ADL's have been carried out successfully ore not. In this section containing activities of daily living, each one of those variables is introduced. Moreover, the role of those variables in proposed approach of this thesis is explained.

AGGIR categorizes autonomy levels to various environmental factors affecting a person's activities and social life. No pathology is considered, although pathology grids can be used with AGGIR to determine the relative costs of pathologies [40]. The resulting levels of autonomy are assigned to equivalent resource groups. Individuals whose score falls in one group would require similar financial, instrumental, or human resources.

Groupe Iso-Resource (GIR) (Table 2.4) helps determine if a person is entitled to a benefit as well as determine the level of benefit the person can receive. The GIR score is based on answers to questions or by observation. The calculator assigns a score between 1 (0 percent

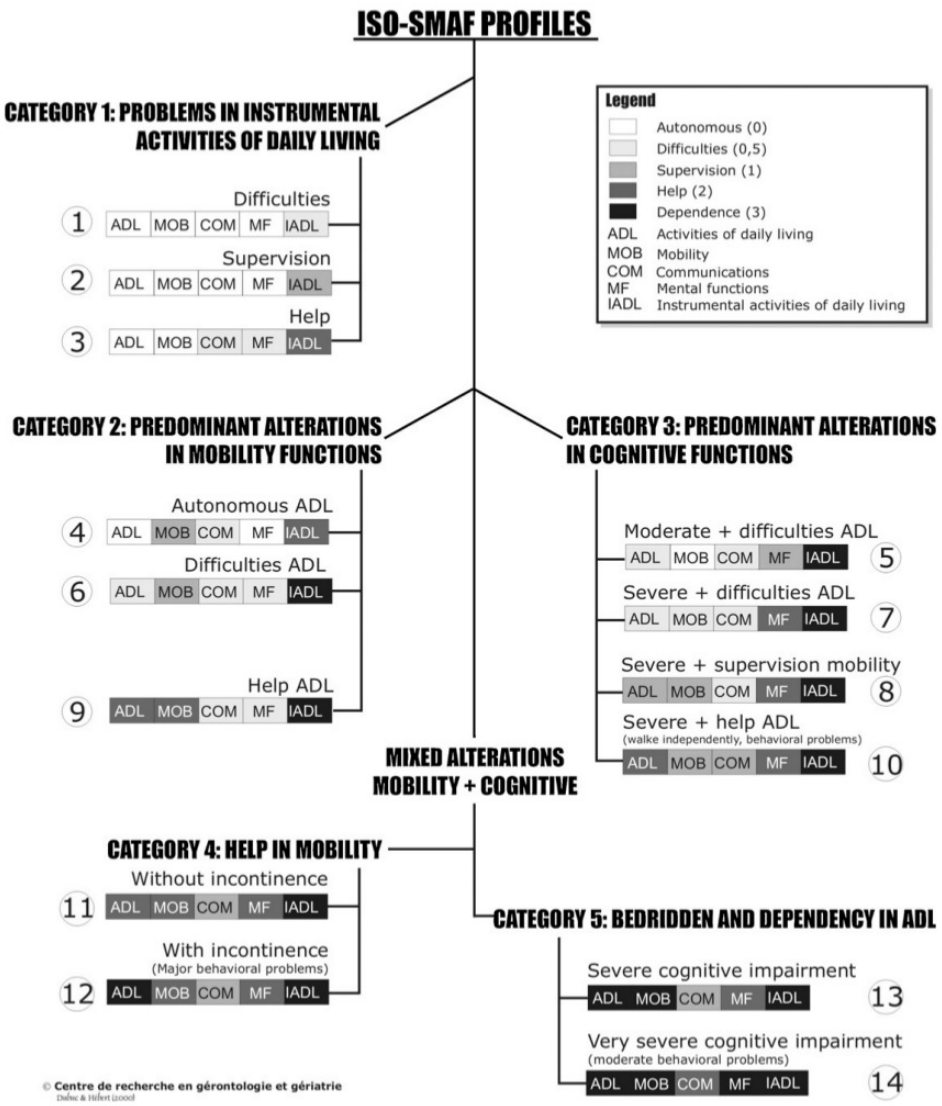


Figure 2.4: 14 Iso-SMAF profiles [141]

autonomy) and 6 (93 percent autonomy). A score below 4 entitles a person to public assistance: full assistance for a score of 1 and partial assistance for a score of 3. A score of 4 may entitle an individual to some assistance. Scores above 4 do not entitle a person to benefits under the national long-term care program (Allocation Personnalisée d'Autonomie, APA). The scores can be used for other purposes, such as insurance claim evaluation [43].

A score of 1 does not mean a disabled person will receive full benefits. For APA, a person must be age 60 or older, and a co-pay may apply based on the financial resources of the individual. The measurement's aim is to be as objective as possible. It should not vary by region or by the evaluator [40].

Seventeen activities are considered in the evaluation. Ten of them are considered "discriminant" variables and apply to the physical environment; they are used to evaluate the level of assistance a person needs to carry on with normal ADL's. Seven "illustrative" variables measure the social environment; they are used to evaluate how much assistance a person needs to lead a normal social life. Each variable is categorized by three major states:

A: The individual cannot complete, needs assistance, or must have someone else do the activity;

Table 2.4: AGGIR Scale Dependency Levels [76]

AGGIR Scale	Dependency Levels
GIR 1	Bedridden or confined to an armchair AND mental faculties severely impaired
GIR 2	Confined OR impaired mental faculties
GIR 3	Help several times a day for ADL's
GIR 4	Loss of autonomy for transferring, sometimes also regarding toileting or dressing, OR mobile but needs help to perform ADLs, including eating
GIR 5	Help for bathing and home care
GIR 6	Autonomous

B: The individual can complete alone, but not spontaneously, or correctly, or habitually, or partially;

C: The individual completes alone, spontaneously, habitually, totally, and correctly.

The 10 discriminatory variables and the 7 illustrative variables are enlisted on Table 2.5; the parameters they evaluate are shown on Table 2.6.

Table 2.5: AGGIR discriminatory variables [43]

Variable	Evaluated parameters
Coherence	Converse or behave in a logical and sensible manner
Orientation	Locates oneself in time, during the day, and on location
Toileting	Evaluates upper and lower body toileting
Dressing	Evaluates upper, middle, and lower body dressing
Alimentation	Evaluates serving and eating
Elimination	Evaluates capacity to manage one's hygiene, not continence; evaluates all eliminations
Transfers	Lying down, sitting down, getting up
Indoor movement	With or without technical assistance
Outdoor movement	With or without technical assistance (outdoors]
Distant communication	Phone, tele-alarm

All the aforementioned dependency evaluation models possess almost the same variables. In this work, The use of the AGGIR grid variables for the developmente of a DSL is proposed. It is important to mention that the proposed DSL can be adapted to the other dependency evaluation models presented in this chapter as well.

2.4 Conclusion

In this chapter we presented a section dedicated to related studies on Pervasive Healthcare. Another section follows to it describing related studies on the categorization for the detection of activities of daily living. Moreover, an identification of the technologies with regard to the

Table 2.6: AGGIR illustrative variables [43]

Variable	**Evaluated parameters**
Management	Manages personal business, budget, handles money
Cooking	Prepares meals
Housekeeping	Can do all of housekeeping tasks
Transportation	Can use different modes of transportation or can order them
Purchases	Mail, phone, internet purchase, or direct purchases
Medical treatment	Follows medical prescriptions
Leisure activities	Cultural activities, sports, pastime

maintenance and monitoring of individuals at home is presented. We present an overview of several models whose aim is the evaluation of the performance of activities of daily living at home.

Chapter 3

Proposal of a Domain Specific Language for the Representation of the AGGIR Constants

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In this chapter, we present a Domain Specic Language (DSL), which uses operators in order to deal with time and location of activities and event detection constraints. The proposed DSL is intended to describe activities performed by an elder person within a smart home environment and to identify the AGGIR grid variables, thus determining his level of independence. We provide an overview of the existing works that serve as a background for our approach. Then, we present the detailed description of the DSL; as well as the orchestration for the detection of activities of daily living according to the AGGIR grid variables.

3.1 State of the Art

To support the recognition of Activities of Daily Living (ADL's) performed at home by elderly/handicapped people, many works have proposed the development of DSL's. In this section, we first review the scientific literature related to the different types of DSL's in any context

(logic languages, textual languages, and graphical languages). Afterward, we dedicate on the revision of existing DSL's in the context of ADL's description and recognition.

A DSL is a programming language [123, 178], which helps developers to define concepts in terminology belonging to a particular domain [166]. Additionally, DSL's are conceived as small textual languages which are able to take certain narrow parts of programming and make them "easier to understand and therefore quicker to write, quicker to modify, and less likely to breed bugs". Their main goal is to improve developers' productivity as well as reducing the communication gap in software development between programmers and domain experts [48]. Moreover, DSL's are considered as an increasingly popular software development technique, which uses concepts from the problem domain rather than the solution domain [57].

DSL's are separated into two categories based on their design: internal DSL's and external DSL's [48]. An internal DSL (also called embedded DSL) provides a general-purpose host language to solve domain-specific problems (originally based on the LISP programming language [66]). Due to the fact that an external DSL is independent from any other language, they need their own infrastructures like parsers, linkers, compilers, or interpreters [44]. External DSL's represent 50% of the DSL's [89].

Moreover, patterns [123] and design guidelines [81] have been proposed for the developement of DSL's. The aformentioned group of guidelines are classified by: purpose, realization, content, concrete and abstract syntax; as shown on Table 3.1. According to the concrete language, purpose, and domain; some guidelines might be contradicting or irrelevant [81], so they should be considered as proposals when designing a DSL [184].

Table 3.1: Categories of DSL design guidelines proposed by Karsai et al. [81].

Category	Description	Guidelines
Language purpose	Goal of the DSL	1. Identify language uses early 2. Ask questions 3. Make your language consistent
Language realization	Implementation of the DSL	4. Decide carefully whether to use graphical or textual realization 5. Compose existing languages where possible 6. Reuse existing language definitions 7. Reuse existing type systems
Language content	Elements of the DSL	8. Reflect only the necessary domain concepts 9. Keep it simple 10. Avoid unnecessary generality 11. Limit the number of language elements 12. Avoid conceptual redundancy 13. Avoid inefficient language elements
Concrete syntax	Readable (external) representation of the DSL	14. Adopt existing notations domain experts use 15. Use descriptive notations 16. Make elements distinguishable 17. Use syntactic sugar appropriately 18. Permit comments 19. Provide organizational structures for models 20. Balance compactness and comprehensibility 21. Use the same style everywhere 22. Identify usage conventions
Abstract Syntax	Internal representation of the DSL	23. Align abstract and concrete syntax 24. Prefer layout which does not affect translation from concrete to abstract syntax 25. Enable modularity 26. Introduce interfaces

Several DSL's have been developed for different areas of application, e.g., expert rules, business rules, configuration rules. A systematic mapping study is presented in [89].

Logic languages are a group of languages that choose to define events as a logic style formula (i.e., first order logic). In general, logic languages for complex event detection are based on the use of operators concerning to temporal and spatial relations of events, so they can be described and recognized.

The most common approach is to write requirements using natural language [60]. This can be used for different purposes to describe any kind of requirements and functional specifications for information systems [140].

A conceptual work in [36] expresses how business logic can be translated by means of automated code execution for the creation of logic-based smart contracts. Moreover, two execution modes for smart contracts are highlighted: lazy execution (initiated by an actor, either manually or scheduled) (Fig. 3.1); and eager execution (fully automated transactions).

```
<Reaction style="passive">
   <event>
      <Message mode="inbound">
         <oid><Var>PaymentID</Var></oid>
         <protocol>Protocol</protocol>
         <sender>SenderPublicKey</sender>
         <receiver>ContractPublicKey</receiver>
         <content>
                <Var>Amount</Var>
         </content>
      </Message>
   </event>
   <body>
      <Naf>
         <Atom>
                <Var>NoObligationLeft</Var>
                <Var>T</Var>
         </Atom>
      </Naf>
   </body>
   <action>
                                        <Assert>
                                          <Message mode="outbound">
                                            <oid><Var>PaymentID</Var></oid>
                                            <protocol></protocol>
                                            <sender>ContractPublicKey</sender>
                                            <receiver>
                                                   NetworkNodes
                                            </receiver>
                                            <content>
                                                   <Var>Balance</Var>
                                            </content>
                                          </Message>
                                        </Assert>
                                      </action>
                                    </Reaction>
```

Figure 3.1: Smart contract code example provided by de Kruijff and Weigand [36]

IoTDSL, a prototype DSL meant to allow end users drive the IoT devices installed in their homes relying on a high-level rule-based language is presented in [10] (Fig. 3.2); in order to achieve definition and manipulation of devices which are deployed in home environments. Users are able to describe and combine event-based semantics as well as structural configurations in a declarative manner; with a high-level representations of devices. The orchestration of events is then analysed to a component in charge of translating high-level rules into a complex event processing facility dedicated to evaluate runtime events. Moreover, the proposed prototype relies upon a textual syntax; and simulation code can be generated to play configurations defined by the user.

A framework is proposed in [128] regarding complex event reasoning concerning process, integration, and provision of reasoning in order to address decision support to supply chain planners whenever information about disruption events (such as process failure) is incomplete and/or uncertain, by using logical and probabilistic reasoning approaches. Some of the operators employed in the aforementioned approach for semantic complex event processing are enlisted on Table 3.2.

A DSL called ReqDL for describing requirements and capturing bidirectional traceability data, concerning system modeling elements is introduced in [60]. Additionally, a generation

```
gateway Middleware
device DoorDetector {
  sensing opened()
  sensing closed()
}
device MotionDetector {
  sensing moving()
}
device ToggleSwitch {
  sensing toggled()
}
device LightSensor {
  sensing light()
}
device LightBulb {
  actuating on()
  actuating off()
}
device Alarm {
  actuating sound()
}
```

Figure 3.2: Type declarations in [10].

Table 3.2: Complex event detection operators proposed by Nawaz et al. [128]

Operator	Description
SEQ	The *SEQ* operator identifies a given sequence of events from the input events.
PAR	The *PAR* operator identifies a pattern of two or more events occurring at the same time either overlapping completely or partially
DURING	This complex event is detected when an events occurs during an interval when another event is happening.
STARTS	Indicates when two events start at the same time.
FINISHES	Indicates when two events finish at the same time.
COUNT	Indicates the number of occurrences of an event during a time period.
OR	This complex event is detected when one event occur out of two or more events during a time interval.
AND	The *AND* operator identifies the occurrence of two or more events in any order during a time interval.
NOT	Any event does not happen or exist at time t.

algorithm for independent trace models is presented; as well as concrete and abstract syntax in terms of grammar and metamodel (Fig. 3.3). Also, three types of operators are proposed to describe requirements and capture trace data: attributes, description, model elements, and trace links. Moreover, a working example is also provided.

A graphical DSL provides domain experts with an intuitive and user-friendly tool to define the complex event processing domains of interest for which critical situations in real time need to be detected [22]. Some recent work on this research field are presented.

Dolphin, an extensible programming language implemented as a Groovy DSL for autonomous vehicle networks is described in [107] (Fig. 3.4(a)). It is designed to express an orchestrated execution of tasks defined for multiple vehicles dynamically available in a network. Additionally, the built-in operators include support for composing tasks in several forms, i.e., instance according to concurrent, sequential, or event-based task flow, partially inspired by process calculi approaches. Moreover, the integration of the aforementioned DSL with an open-source toolchain for autonomous vehicles is described, in which, users are able to edit and run Dolphin programs through a custom window, embedded in the overall GUI environment for editing and monitoring (Fig. 3.4(b)). Also, results from field tests using unmanned underwater vehicles and unmanned aerial vehicles are presented.

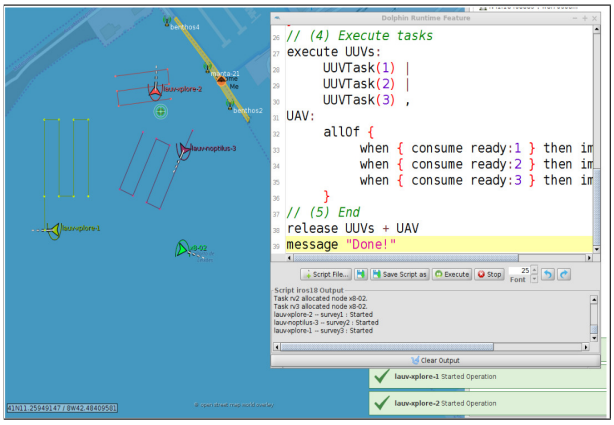
All these works demonstrate the utility of ifferente types of DSL's in several domain. In the following section some works regarding DSL's describing the detection of ADL's are introduced.

ReqDL Operators and attributes	Description
Attributes	
identifier	unique identifier of the requirement
name	name of the requirement
traceable	the Boolean status stating whether the requirement is traceable.
level	determines the definition level of the requirement in a form of {Client requirement, System requirement, Component requirement}
type	determines the type of the requirement {General, Functional, NonFonctional, Physical, Design}
include	includes contexts and their attributes in order to associate extra information with the requirement, it may be the source or the author of the requirement .
description	describes a syntactic structure of the requirement functionality using different operators
Modal Operators	
shall, will or should	denote respectively legally obligatory, future, or urgently recommended requirements
Temporal and logical operators	
when, where	requirement action is performed or provided under certain temporal or logical constraints
Action Operators	
action ..	Autonomous action
provide ..with the ability to	Interactive action
be able to ..	Passive action
using	determines the element of the system allowing to perform, to refine, to satisfy, or to verify the action of the requirement

Figure 3.3: Excerpt of Operators and Attributes definition proposed by Haidrar et al.[60]

```
Task := PlatformTask              // Platform task
     | action '{' Code '}'        // Program-level action
     | condition '{' Cond '}'     // Program-level condition
     | Task '>>' Task             // Sequential composition
     | Task '|' Task              // Concurrent composition
     | Task '[' VSet ']'          // Vehicle set allocation
     | allOf '{' WhenThen+ '}'    // All-of block
     | oneOf '{' WhenThen+ '}'    // One-of block (choice)
     | waitFor '{' Cond '}'       // Execution subject
       then Task                  //   to start condition
     | until '{' Cond '}'         // Execution subject
       run Task                   //   to stop condition
     | idle Time                  // Idle task
     | during Time                // Execution subject
       run Task                   //   to time limit
     | watch Task                 // Error handling
       onError '{' Code '}'
WhenThen := when '{' Cond '}' then Task
// For IMC-based platform
PlatformTask := imcPlan '(' Id ')'
              | imcPlan '{' IMC_DSL_Spec '}'
```

(a) Grammar for Dolphin tasks



(b) Dolphin GUI environment

Figure 3.4: Grammar and GUI environment for Dolphin language [107]

3.1.1 DSL for the detection of ADL's

Authors in [126] introduce a smart city oriented infrastructure for collecting and managing data related to behavior patterns concerning elderly people and their daily activities, both in indoor and outdoor environments. Validation considering both low-level and high-level use cases was carried out. Part of the grammar employed regarding user motility and indoor-outdoor localization is presented: *BODY_STATE_START/ BODY_STATE_STOP* for indicating the change of a particular body state of the subject (i.e. still, walking, sleeping, etc.); *POI_ENTER/POI_EXIT* for managing the location type and/or the GPS coordinates. Furthermore, the user-environment interection is described by activities such as *FURNITURE_OPEN/ CLOSED* for sensing contact, motion and vibration on furniture and tools. Furthermore, *state_type*, *location_type* are defined in order to identify the performance of activities.

Authors in [104] proposed a DSL for model-driven development of activity-oriented context-

aware applications, in order to facilitate the development by improving the efficiency of developers. The concept model of such applications is analyzed, in order to design abstract syntax and concrete syntax (Fig. 3.5). Implemented tools include the development environment as well as the generation of Java code and ontology specification. A case study and evaluation concerning a smart meeting room was introduced to demonstrate the utilities of the proposed approach.

```
<DomainModel>            ::=  <EnvModel> | <AppModel>
<EnvModel>               ::=  "envPackage" <QualifiedName> "{" {<Feature> | <Owner>}"}"
<Feature>                ::=  "feature" <ID> "{"
                              "owner_type" <OwnerType>
                              "probe_type" <ProbeType> {<ProbeType>}
                              "actuator_type" {<ActuatorType>}
                              "operator" {<JudgeFun>}"}"
<ActuatorType>           ::=  <ID>
<ProbeType>              ::=  <ID>
<Owner>                  ::=  "owner" <ID> ":"<OwnerType>"{"{<Probe> | <Actuator>}"}"
<OwnerType>              ::=  "Location"|"Person"
<Actuator>               ::=  "actuator" <ID> ":"<ActuatorType>
<Probe>                  ::=  "probe" <ID> ":"<ProbeType>
<AppModel>               ::=  "appPackage" <QualifiedName> "{" {<ConstraintType>}"}"
<ConstraintType>         ::=  <DefaultConstraint> | <PersonalizedConstraint>
<DefaultConstraint>      ::=  "activity" <ID>
                              "constraint" {<Constraint>}
<PersonalizedConstraint> ::=  "person" <ID>
                              "activity" <ID>
                              "constraint" {<Constraint>}
<Constraint>             ::=  <ID>":"[ "["<TimePeriod>"]" ] {<Assertion>}
<TimePeriod>             ::=  <ID>
<Assertion>              ::=  "assertion" <AtomicAssertion>{<AtomicAssertion>}
<AtomicAssertion>        ::=  <ID> "," <JudgeFun> "," <Threshold>
<QualifiedName>          ::=  <ID>{"."<ID>}
<JudgeFun>               ::=  ("<"|">")["="]|"="|"<>"|"inRange"
<Threshold>              ::=  <Float> |("["|"(")<Float>","<Float>(")"|"]")
<Float>                  ::=  ["+"|"-"]((<INT>["."<INT>])|("."<INT>))
```

Figure 3.5: Syntax definition of the approach introduced by Li et al.[104]

An ambient assisted living architecture for the monitoring of elderly people is presented in [117] (Table 3.3). The system is able to collect all information coming from the heterogeneous sensors located in the indoor environment, such as environmental parameters or biomedical information, and to forward it towards a remote service. The proposed system is able to continuously monitoring the elderly locomotor activity. Additionally, the system can trigger specific events when dangerous situations occur (e.g., fall detection). The feasibility of the proposed architecture was demonstrated by validation functional tests implementing a real supporting the elderly subject during his daily life activities.

Table 3.3: Grammar proposed by Mainetti et al. [117]

Shock topic properties		**Fall topic properties**	
Topic Name	Shock		
Description	It models the event of a sudden acceleration of the under examination subject along the vertical axis. The topic gets updated by the accelerometer worn by the person	Topic Name	Fall
		Description	It models the event of fall of the person to be monitored
Type	Low-Level Topic	Type	High-Level Topic
Feature	Acceleration	Feature	Event of fall
Location	e.g., it:lecce:Garibaldi_street:71:grandma_home	Location	e.g., it:lecce:Garibaldi_street:71:grandma_home
Value	String value coming from the accelerometer and saved in the topic. It consists of a tern of values: - Time Window: timespan in milliseconds, in which samples are sent from the accelerometer. - Sample number: number of samples sent in the time window - Measure: acceleration along three axes of reference.	Value	boolean

Authors in [26] presented a study based on a model-driven solution for a top-down approach

for rapid design and prototyping of an ambient assisted living capable of detecting the behaviour of elderly persons in their home, acquiring data through a sensor tag wristband that sends data to a smartphone application through bluetooth low energy protocol. Grammar and attributes for the proposed model-drive approach are enlisted on Table 3.4. The list of the detected low-level activities are: body state, indoor home monitoring, presence in indoor places, presence in outdoor places, smartphone usage, usage of home appliances, interaction with transportation and ambient parameters. Moreover, an example of grammar for low-level activities for the moving status concerning the *start* and *stop* moving actions is presented on this work and represented on Fig. 3.6. It includes *START_MOVING* (Fig. 3.6(a)) and *STOP_MOVING* (Fig. 3.6(b)). Also, it is possible to calculate the duration of body state status along with the *STILL_TIME* value. Such a duration can be computed and treated as a measure.

Table 3.4: Description and attributes of low-level activivities in [26]

Property	Description	Type
Action	Name of the action executed by a user	URN String
Location	Location where the action is executed	URN String
Payload	User performing the action Sensor tag device name Sensor tag device MAC address	String
Timestamp	Timestamp of the action	String
Rating	A value defining the uncertainty of the inferred action (1.0: max certainty, 0.0: unaffordable)	Float [0..1]
Extra	It can wrap information that are not mandatory but are useful for the current analysis.	JSON
Secret	It contains a token needed to grant security.	String


```
02-09 16:12:13.401 15018-15018/com.lwox.core D/BleIdentityReceiver:
Topic ricevuto
02-09 16:12:13.401 15018-15018/com.lwox.core D/Topic:
{"action":"eu:c4a:action:START_MOVING","extra":{"pilot":""},"locatio
n":"it:puglia:lecce:testlocation","payload":{"mDeviceAddress":"C4:BE
:84:70:17:09","mDeviceName":"CC2650
SensorTag","user":"eu:c4a:pilot:lecce:user:USER_01"},"rating":0.4,"s
ecret":"token","timestamp":"2017-02-09 16:12:07.181"}
```


(a) *START_MOVING* action


```
02-09 16:10:48.831 15018-15018/com.lwox.core D/BleIdentityReceiver:
Topic ricevuto
02-09 16:10:48.831 15018-15018/com.lwox.core D/Topic:
{"action":"eu:c4a:action:STOP_MOVING","extra":{"pilot":""},"location
":"it:puglia:lecce:testlocation","payload":{"mDeviceAddress":"C4:BE:
84:70:17:09","mDeviceName":"CC2650
SensorTag","user":"eu:c4a:pilot:lecce:user:USER_01"},"rating":0.4,"s
ecret":"token","timestamp":"2017-02-09 16:10:45.424"}
```


(b) *STOP_MOVING* action

Figure 3.6: Example of low-level activity provided in [26]

An DSL for processing online events targeting binary sensors is presented in [185]. The approach is limited to handling binary sensors, due to the fact that the proposed operators are

defined on the domain of boolean signals (Fig. 3.7). The aforementioned language provides a primitive notion of state, modeled as a boolean signal over time, and allows the generation of complex conditions on different states using signal operators. Additionally, an interpreter for the language was implemented and applied it to rewrite a set of real ambient assisted living services.

```
select Slot, Open, Coffee from pattern [
  ( every Slot=Event(type='Calendar', status!='end') ->
      Open=Event(type='Cupboard', status='open')
      and Coffee=Event(type='CoffeeMaker', status='on')
      and not ( Event(type='Calendar', status='end') ) )
  or
    ( every Open=Event(type='Cupboard', status='open') ->
        Slot=Event(type='Calendar', status!='end')
        and not ( Event(type='Cupboard', status='close') ) ->
          Coffee=Event(type='CoffeeMaker', status='on')
          and not ( Event(type='Calendar', status='end') ) )  ]
```

Figure 3.7: Code example provided by Volanschi et al. [185]

Table 3.5 summarizes and evaluates the most recent DSL approaches regarding the services they provide, the categories of monitored daily activities, sensing types and geriatric models.

Table 3.5: Comparison among the most recent DSL approaches regarding ADL's

Work	Services	Activities	Sensing	Sensing Type	Geriatric models
[26]	Movement tracking	IADL	Single	BSN	No
[104]	Activity-oriented context-aware applications, energy	ADL	Multi	PSN	No
[117]	Wellness determination, fall detection,mouvement tracking, energy	IADL	Multi	PSN, BSN	No
[126]	Detection of elderly behaviour patterns, mouvement tracking	ADL, IADL,	Multi	PSN, BSN	No
[185]	ADL estimation, energy	ADL	Multi	PSN	No

All these works consider the correct identification of the activities that require analysis of ADL's. However, there is still a lack of ADL's to be detected, while others only focus on a subset of specific activities; but most importantly, they are not based on a specific tool such as the AGGIR grid.

Subsequently, in section 3.1.2, a review of several operators able to describe time and location relations among events is introduced.

3.1.2 Complex Event Operators

In this section, we present a review of different operators used to describe time and location relations among events. Actions and activities that can be identified in a space are called events. These events can be tagged with time and location, that in turns make events be related according to the moment and location in which they occur. discuss details concerning logic languages.

Temporal, Localization, and Events Operators: A Review

In this section, we present a review of different operators used to describe time and location relations among events. Actions and activities that can be identified in a space are called

events. These events can be tagged with time and location, that in turns make events be related according to the moment and location in which they occur.

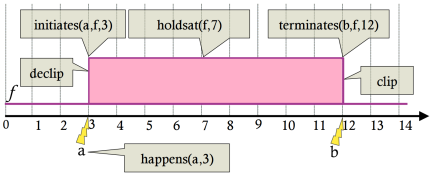
According to [33], in order for a system to make sensible decisions, it has to be aware of where the users are and have been during some period of time. Spatial and Temporal logic is a well established area of Artifitial Intelligence (AI) [105], which has been applied to represent and reason on spatial and temporal features and constraints of context and situations [190]. For instance, temporal knowledge on human activities can be specified by means of the temporal operators `ANDlater` and `ANDsim` in Event-Condition-Action rules introduced by [12]. The work proposed by [56] applies Allen's Temporal Logic [6] (Table 3.6) to describe, constrain, and reason on temporal sequences in dealing temporal and spatial knowledge in smart homes as well.

Table 3.6: Allen's temporal operators [6]

Relation	Symbol	Symbol for inverse	Illustration
X *before* Y	$<$	$>$ (*after*)	X Y
X *equals* Y	$=$	$=$ (*equals*)	X Y
X *meets* Y	m	mi (*met by*)	X Y
X *overlaps* Y	o	oi (*overlapped by*)	X Y
X *during* Y	s	di (*contains*)	X Y
X *starts* Y	d	si (*started by*)	X Y
X *finishes* Y	f	fi (*finished by*)	X Y

The event calculus of Shanahan [161] infers what is true from information that expresses what and when something occurs (actions) and what happens after those actions. Shanahan uses the action concept instead of event, but it makes no difference between the two. The notion of fluent is used to express anything that can change over time, as seen on Table 3.7.

Table 3.7: Shanahan's event calculus formulas [161]

Formula	Meaning	Illustration
Initiates(α, β, τ)	Fluent β starts to hold after action α at time τ	
Terminates(α, β, τ)	Fluent β ceases to hold after action α at time τ	
InitiallyP(β)	Fluent β holds from time 0	
$\tau_1 \leq \tau_2$	Time point τ_1 s before time point τ_2	
Happens(α, τ)	Action α occurs at time τ	
HoldsAt(β, τ)	Fluent β holds at time τ	
Clipped(τ_1, β, τ_2)	Fluent β is terminated between times τ_1 and τ_2	

The semi-intervals proposed in [50] are a generalization of Allen's interval-based approach to temporal reasoning. Semi-intervals correspond to temporal beginnings or endings of events. Allen's approach was modified to an interval-based representation of temporal relations; so it can be used for reasoning with incomplete knowledge about temporal relationships. Relations defined between semi-intervals are "older", "younger", "head-to-head", "survives", "survived by", "tail to tail", "precedes", "succeeds", "contemporary", "born before death", "born after death", "died after birth" (Table 3.8). Additionally, the notion of conceptual neighborhood is essential in this work; in which events are not treated as isolated entities; but as embedded conceptual items in a network of related events.

Table 3.8: Freksa's temporal operators [50]. Eleven semi-interval relationships. Question marks (?) in the pictorial illustration stand for either the symbol denoting the event depicted in the same line (X or Y) or for a blank. The number of question marks reflects the number of qualitatively alternative implementations of the given relation.

Relation	Symbol	Symbol for inverse	Description	Illustration
X is older than Y	ol	—	The beginning of X is less than the beginning of Y	*XXX????*
Y is younger than X	—	yo	The beginning of X is greater than the beginning of Y	*YY*
X is head to head with Y	hh	hh	The beginnings of X and Y are equal	*XXX??*
	hh			*YYYY*
X survives Y	sv	—	The ending of X is greater than the ending of Y	*????XXX*
Y is survived by X	—	sb	The ending of X is less than the ending of Y	*YY*
X is tail to tail with Y	tt	tt	The ending of X is equal to the ending of Y	*??XXX*
				YYYY
X precedes Y	pr	—	The ending of X is not greater than the beginning of Y	*XXX?*
Y succeeds X	—	sd	The beginning of X is not less than the ending of Y	*YYY*
X is a contemporary of Y	ct	ct	The intersection of X and Y is not empty	*?XXX???*
				???YYY?
X is born before death of Y	bd	—	X does not precede Y	*XXX?????*
Y died after birth of X	—	db	X does not succeed Y	*?????YYY*

Five crisp relations were introduced in order to extend the modelling of the temporal reasoning model in [149]. Those relations can hold between a time point and a time interval; and can be derived from the thirteen Allen's temporal relations. The aproach relies on the assumption that the time interval degenerates into a time point, i.e. $X+ \rightarrow X$-. These new relations hold between a time point and a time interval where $\bullet$ represents a time point and $\underline{XXXXX}$ represents a time interval; as shown on Table 3.9.

A study proposed by [11], presents an ontology-based framework capable of handling complex event modeling and detectiion in Multimedia Sensor Networks (MSN's). The framework helps users model all readings from MSN's into our proposed ontology-based data model through JSON files. Moreover, translating of semantic formation, detecting, and reporting the events in

Table 3.9: Relations time points (tp) - time interval (x) Ribarić and Dalbelo Bašić [149]

Relation	Symbol	Symbol for inverse	Illustration
tp before Y	<	>	•XXXX
tp during Y	d	None / Not existing	XX•XXX
tp starts Y	s	None / Not existing	• XXXXX
tp finishes Y	f	None / Not existing	XXXXX •

a near real-time manner are also possible in the aforementionned approach. For this purpose, event/location related operators were proposed. Such operators are enlisted on Table 3.10.

Table 3.10: Event/Location operators proposed by Angsuchotmetee et al. [11]

Event/Location	
Topological Relations:	equals, disjoint, intersects,touches, contains, covers, covered by, within, overlaps, crosses.
Distance Relations:	closeTo, farFrom
Directional Relations:	leftOf, rightOf, opposite, above,below

A system that proposes classical conditioning model in order for an agent to recognise patterns of complex sequences of events based on a set of geometrical changes within the observed environment; is presented in [51]. Table 3.11 enlists the names and definitions of the event types that are proposed in [51].

The region connection calculus (RCC); an interval logic theory that can be used to reason about space is introduced in [143]. The RCC theory is a first-order logic theory developped based on the notion of connection. This approach explains several topological relations by means of a connection primitive and compositional operations of first-order formulae. The complete set of relations described in this work are presented on Table 3.12.

A calculus that is described by one object in a subject's visual field which can be positioned relatively to another in the temporal and spatial domains is introduced in [52]. The aforementioned approach is defined by the line-of-sight (LOS) relations; and it is developped in an analogous way to the treatment of temporal intervals proposed by [6, 50]. Such relations are: "*clear of*" (*C*); "*just clear of*" (*JC*); "*partially hides*" (*PH*); "*partially hidden by*" (*PHI*); "*just hides*" (*JH*); "*just hidden by*" (*JHI*); "*hides*" (*H*); "*hidden by*" (*HI*); "*exactly hides*" (*EH*); "*exactly hidden by*" (*EHI*); "*in front of*" (*F*); "*has it in front of it*" (*FI*); "*just in front of*" (*JF*); "*has it just in front of it*" (*JFI*); as shown on Fig. 3.8.

The work proposed by [142], extends the research of [143, 52]. This work introduces the region occlusion calculus (ROC-20); that describes occlusion events of mutually occluding bodies to model spatial occlusion by allowing both convex and concave shaped bodies into the modelled domain. The relations of the aformentioned research are illustrated on Fig. 3.8.

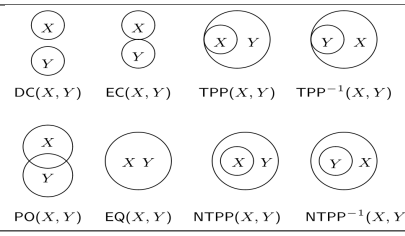
More research works regarding location and event operators are presented in [24, 88, 136, 139, 158, 192]; as presented on Table 3.13 and Table 3.14.

The reviewed works proposing operators concerning temporal, spatial, and event-related

Table 3.11: Event/Location operators proposed by Furze and Bennett [51]

Event/Location	
Approaching(X,Y)	X and Y are approaching each other.
Receding(X,Y)	X and Y are receding from each other.
Static(X,Y)	The distance separating X and Y does not change
MergeR(X,Y)	X is merging with Y on the right of Y.
MergeL(X,Y)	X is merging with Y on the left of Y.
MergeT(X,Y)	X is merging with Y on the top of Y.
MergeB(X,Y)	X is merging with Y on the bottom of Y.
EmergeR(X,Y)	X is emerging from Y on the right of Y.
EmergeL(X,Y)	X is emerging from Y on the left of Y.
EmergeT(X,Y)	X is emerging from Y on the top of Y.
EmergeB(X,Y)	X is emerging from Y on the bottom of Y.
MakeCR(X,Y)	X has made contact with Y on the right of Y.
MakeCL(X,Y)	X has made contact with Y on the left of Y.
MakeCT(X,Y)	X has made contact with Y on the top of Y.
MakeCB(X,Y)	X has made contact with Y on the bottom of Y.
BreakCR(X,Y)	X has broken contact with Y on the right of Y.
BreakCL(X,Y)	X has broken contact with Y on the left of Y.
BreakCT(X,Y)	X has broken contact with Y on the top of Y.
BreakCB(X,Y)	X has broken contact with Y on the bottom of Y.
MoveRight(X)	X has moved right.
MoveLeft(X)	X has moved left.
MoveUp(X)	X has moved up.
MoveDown(X)	X has moved down.
Lost(X)	Object X has ceased to be detected.
Found(X)	Object X has been newly detected.

Table 3.12: Location operators proposed by Randell et al. [143]

Relation	Description	Illustration
DC(x, y)	x is disconnected from y	
P(x, y)	x is a part of y	
x = y	x is identical with y	
PO(x, y)	x partially overlaps y	
EC(x, y)	x is externally connected with y	
TPP(x, y)	x is a tangential proper part of y	
NTPP(x, y)	x is a nontangential proper part of y	

operators are summarized on Table 3.15. to provide a significant contribution to a solution of these problems.

In this section, remarkable works concerning the literature describing temporal, location and event operators were reviewed. Next, the main characteristics a proposal of a DSL for the detection of the AGGIR constants are presented.

3.2 Domain Specific Language

After reviewing the corresponding state of the art, a DSL is developed in order to express situations related to the AGGIR variables that respond to the activities performed by people with a physical or mental disability, support for elderly, diseases connected to aging; which will

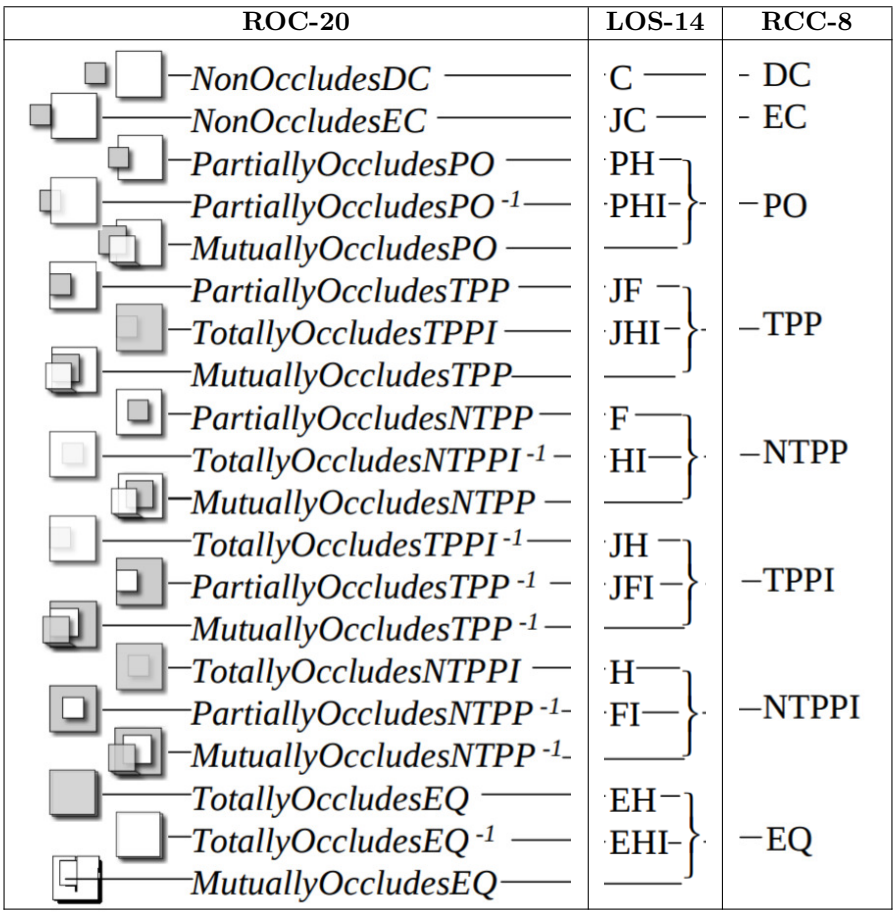


Figure 3.8: Comparison among the relations of ROC-20 [142], LOS-14 [52] and RCC-8 [143]

allow to express situations related to the maintenance of people at home. For carrying out such identification, sensors to identify the ADL's are specified (sections 3.2.1 and 3.2.2); as well as the orchestration for atomic (section 3.3.1) and complex event detection (section 3.3.2).

Moreover, the features that the proposed DSL provides are the recovery of data from health related sensors and home-related sensors defined and described through the DSL; in order to perform operations regarding a specific date or a time range starting from a particular date or between two-time points, in addition to the identification of both atomic and complex events.

Depending on both the scope and the user community it targets, there exist several definitions for a DSL [32, 123, 179]. The language must be able to describe the data that one wishes to recover from the various sensors present in a house and the operations related to them.

The purpose of WSN's is to detect a user's vital signs, activities and surroundings. To achieve this goal, a set of sensors is needed to measure vital signs from the inhabitant. Moreover, smart home sensors need to be deployed to monitor the surroundings in a home environment; so it is possible to identify the activities associated with the AGGIR constants, considering physiological contexts and environmental contexts.

For this purpose, sections 3.2.1 and 3.2.2 introduce smart home sensors and health related sensors, respectively.

Table 3.13: research works regarding location and event operators

	Work	Excerpt of code

Bruno et al. [24]	Design of an heterogeneous information management framework, allowing for the description of a wide variety of human activities in terms of multi-modal environmental and wearable sensing data and providing accurate knowledge about the user activity to any assistive robot.	`(SimpleOperator`
		`(Head Human::ClimbStairs())`
		`(RequiredState req1 Posture::Standing())`
		`(RequiredState req2 Gesture::Walk())`
		`(RequiredState req3 Location::Staircase())`
		`(RequiredState req4 Location::EntranceHall())`
		`(Constraint During(Head,req1))`
		`(Constraint During(Head,req2))`
		`(Constraint Equals(Head,req3))`
		`(Constraint MetByOrAfter(Head,req4))`
		`)`

Kim et al. [88]	Smart home ontology model (SHOM) used in a home monitoring framework. Both a general architecture and an autonomic decision making system for a smart home environment are proposed. The ontology-based context model relies on OWL and role-based reasoning using SWRL (semantic Web rule language) for assisting the elderly as well as understanding the subject's context. Environmental wireless sensors and ECG monitoring medical sensor were employed for collecting data	If the elderly is on his bed and the TV is off and the light is off, then the elderly person is sleeping. If the elderly person is sleeping then set the temperature in the room to 23 degrees Celsius. SmartHomeUser(?x) ∧ isInRoom(?x, bedroom) ∧ hasApplianceState(tv_bedroom, false) ∧ hasApplianceState(light_bedroom, false) → hasUserActivityState(?x, sleeping) hasUserActivityState(?x, sleeping) ∧ TemperatureSensor(?y) → changeTheValue(?y, 27)

Patkos et al. [136]	Cerbere,a production system designed to perform online causal, temporal and epistemic reasoning based on the event calculus	`Happens(DoorOpens(Ned,HallBedroom,0), -1)`
		`Happens(DoorOpens(Ned,HallBathroom,100), -1)`
		`Happens(TriggerAlert(NoActivity,340), -1)`
		`Happens(TriggerAlert(NoActivity,580), -1)`
		`Happens(DoorOpens(Ned,HallToilet,636), -1)`
		`Happens(DoorOpens(Ned,HallBedroom,650), -1)`

Pecora et al. [139]	SAM, an architecture for concurrent activity recognition, planning and execution is introduced. The architecture provides a temporal knowledge approach represented based on the Allen's interval algebra relations and constraint-based temporal planning techniques to achieve activity monitoring within an intelligent environment which relies on physical sensing and actuation components	1) HumanAbstract : **Lunch** STARTED-BY Human : **Cooking** FINISHED-BY Human : **Eating** DURING Time : **afternoon** 2) HumanAbstract : **Nap** AFTER HumanAbstract : **Lunch** EQUALS Human : **WatchingTV** 3) Human : **Cooking** DURING Location : **KITCHEN** EQUALS Stove : **ON** 4) Human : **WatchingTV** EQUALS Location : **COUCH** 5) Human : **Eating** DURING Location : **KITCHENTABLE** EQUALS KTRfid : **DISH** 1) Human : **WatchingTV** EQUALS Location : **COUCH** START MovingTable : **DeliverDrink** 2) MovingTable : **DockFridge** MET-BY Fridge : **OpenDoor** 3) MovingTable : **DeliverDrink** AFTER Fridge : **PlaceDrink** 4) MovingTable : **UndockFridge** BEFORE Fridge : **CloseDoor** 5) Fridge : **PlaceDrink** MET-BY MovingTable : **DockFridge** MEETS MovingTable : **UndockFridge** 6) OpenDoor : **OpenDoor** MET-BY Fridge : **GraspDrink**

3.2.1 Smart Home Sensors

For developing a proposal of DSL, it is necessary to acknowledge which sensors must be employed for this matter. With regard to the identification of ADL's by means of several sensors for providing non intrusive monitoring, a group of sensors that can describe such activities are proposed. Also, their main properties / characteristics are explained, as well as their function within the smart-home environment. The aforementioned sensors are enlisted in Table 3.16, where some examples of their use are proposed. Additionally data attributes and data types for each sensor are indicated.

Table 3.14: research works regarding location and event operators

	Work	Excerpt of code
Santos et al. [158]	Probabilistic algorithm for robot self-localisation based on a topological map constructed from the observation of spatial occlusion	$located(R1, v, b, g, r) \leftarrow ((PartiallyOccludesTPPI(b, g, v) \wedge Right(b, g, v) \wedge Further(b, g, v))) \wedge ((NonOccludesDC(b, r, v) \wedge Left(b, r, v))) \wedge ((NonOccludesDC(g, r, v) \wedge Left(g, r, v) \wedge Closer(g, r, v)))$.
Yuan and Herbert [192]	CARA provides context-aware sensor data fusion (including medical and environmental sensors) and incorporates anomaly detection mechanisms that support ADL's analysis and alert generation. The hybrid reasoning architecture incorporates both rule-based and case-based reasoning.	If Activity is not Exercising and (HeartRate is VeryHigh or Respirationrate is VeryHigh) then Situation is Abnormal If SystolicBloodPressure is VeryHigh and DynamicBloodPressure is VeryHigh then Situation is Abnormal If(Activity is Sleeping or Activity is Resting or Activity is watchingtv or Activity is Toileting) and (SystolicBloodPressure is High and DynamicBloodPressure is High) then Situation is Abnormal

Table 3.15: Spatial, temporal and event operators

	Temporal	Location	Event
Freksa [50]	☑	☐	☐
Ribarić and Dalbelo Bašić [149]	☑	☐	☐
Randell et al. [143]	☐	☑	☐
Galton [52]	☐	☑	☐
Randell et al. [142]	☐	☑	☐
Kim et al. [88]	☐	☑	☐
Pecora et al. [139]	☐	☑	☐
Bruno et al. [24]	☐	☑	☐
Patkos et al. [136]	☐	☑	☐
Santos et al. [158]	☐	☑	☐
Furze and Bennett [51]	☐	☑	☑
Angsuchotmetee et al. [11]	☐	☑	☑

Table 3.16: Smart Home Sensors

Sensor type	Attributes	Data type	Examples
Electromagnetic sensor	On/Off	`Boolean`	Cooker/stove; oven; light; switch
Proximity sensor	On/Off	`Double`	Sink
Capacitive sensor	On/Off	`Boolean`	Kitchen; counter; chair
Magnetic sensor	Open/Close	`Boolean`	Refrigerator door; cupboard doors
Presence Sensor	On/Off	`Boolean`	Room occupancy

Moreover, relevant data for each performed task by the inhabitants is considered in Table 3.17, in order to obtain information to achieve the identification of the AGGIR constants after every activity has been carried out to completion.

Table 3.17: Additional data for recognition of activities

Extra data type for each task	Data type
startTime	`Date / String`
endTime	`Date / String`
Duration	`Integer / Double`
Location	`String`
Day	`String / Integer`

3.2.2 Health Related Sensors

As previously mentioned, health care issues within the aging population represent a problem that needs to be addressed in the proposed DSL. Regarding this aim, a group of commercial medical sensors are suggested; such sensors are usually considered as non-intrusive, replaceable and most of them are low cost. Moreover, their main properties / characteristics are explained, as well as their function with the inhabitant within the smart-home environment.

Medical sensors are mainly used in the medical field for the objective of pervasive healthcare. Some of the conventional medical sensors for physiology measurement are listed in Table 3.18. Moreover, each of the devices has specific requirements in terms of parameters, units and collected data.

Table 3.18: Medical sensors [165]

Device	Parameters	Units	Collected Data	
			Data Type	Range
Pulse and Oxygen in Blood (SPO2)	Pulse: 25-250 SPO2 : 35-100	ppm %	Integer Integer	25-250 ppm 35-100 %
Electrocardiogram (ECG)	Heart rate ECG signal	BPM (beats per minute) Volts	Integer Real	0-200 bpm 0/5 V
Airflow	Respiratory rate Breathing intensity	PPM (peaks per minute) Volts	Integer Real	0-60 PPM 0-3.3 V
Blood Pressure Sensor	Systolic pressure Diastolic pressure Pulse	mm Hg mm Hg ppm	Integer Integer Integer	0-300 mmHg 0-300 mmHg 30∼200 ppm
Glucometer	Glucose Glucose	mmol/L mg/dL	Real Real	
Body Temperature Sensor (BTS)	Body Temperature	Degree Celsius (°C)	Real	0-50 °C
Electromyography (EMG)	Muscle rate Muscle signal	CPM (contractions per minute) Volts	Integer Real	0-60 cpm 0-5 V
Spirometer (for breathing measuring)	Volume Air flow	l l/min	Real Integer	0.01∼9.99 L 50∼900 L/min
Galvanic skin response (GSR)	Conductance Resistance Voltage	Siemens Ohms Volts	Real Real Real	0-20 Siemens 10K-100KOhms 0-5V
Body Position	Body position Acceleration	Human body position G	String Real	5 positions
Snore	Snore rate Snore signal	SPM (Snores per minute) Volts	Integer Real	0-60 spm 0-5 V

Additionally, in order to support the needs regarding healthcare issues, several research prototypes have been developed ; i.e. [15, 25, 77, 108, 124, 127, 160, 163].

In order to identify ADL's within a smart-home environment, a group of sensors is presented. In the next section, the main characteristics of the DSL are introduced.

3.2.3 Main characteristics of the proposed DSL

Due to the fact that understanding the process under which the proposed DSL works, it is relevant to highlight the most remarkable characteristics of the proposed DSL: (i) expressing situations related to the AGGIR variables that respond to the activities performed by the elderly/handicapped people at home; (ii) the representation of attribute-based event conditions; (iii) spatio-temporal event conditions are also represented by the DSL. Those are defined by temporal operators such as *Before, During, After*, etc.

To this end, the representation of the DSL realies on a graphical user interface (GUI), in order to describe complex events. In this context, a complex event is considered as an activity performed by an inhabitant that is detected by several sensors at the same time.

DSL interface. Due to its ease to handle, the proposed approach considers a graphical DSL rather than a textual language, since the the future user might not be necessarily a person who is acknowledged in the programming field.

Data recovery from sensors is crucial for the detection of ADL's. For this matter, the proposed DSL plays an important role by gathering information related to the sensed environments; as well as returning graphical results by means of the aforementioned GUI.

Additionally, the information present in the results can be saved as textual specifications in order to be reused, and thus facilitating to find the analysed data without performing any manipulation once again. This functionality allows its reusability by different context-aware applications, thus, not being limited only to the AGGIR variables.

DSL operations. The textual specifications generated by DSL GUI can be used to describe events from an operation perspective. Such as an operation is in charge of measuring one of the following options: a value, a maximum or minimum value, an average of a set of values, or graphically displaying measured values within a time domain. The operations described below were employed for developing the aforementioned interface:

- The `Value` operation: which returns the value (s) of the device.
- The `Maximum` operation: which returns the maximum value of the value (s) of the device.
- The `Minimum` operation: Returns the minimum of the value (s) of the device.
- The `Average` operation: which returns the average of the value (s) of the device.
- The `Graphic` operation: returns an icon with the value (s) of the device.

In addition, due to the fact that events within a smart home environment are sensed during a specific time range,multiple possibilities to describe time using DSL are considered. This includes determining a specific date or description of a time range starting from a particular date or between two-time points representing the beginning and end of the domain. The specified time points can be either a date for a day or hours within a day:

- The operation `Value` can be calculated for the values:
  - On a specific date.
  - Between two hours.
  - Between two dates.
  - From a specific date.

- The operations: `Maximum`, `Minimum`, `Average`, `Graphic`, will be calculated for the values:
  - Between two dates.
  - From a date.
  - Total (all available values for the device).

After selecting the operation as well as the desired calculation means, it only remains to specify the date or the time according to what has been previously selected.

Moreover, for a better understanding regarding the functionalities of the proposed DSL, the DSL features are pictorially exemplified through Fig. 3.9 to Fig. 3.13; where an example of data recovery from an electromyography (EMC) device is presented:

- It is possible to show the devices belonging to a specific user. That is, when the DSL main menu is displayed on the DSL GUI, the selection of the inhabitant from a drop-down list located at the upper-left corner is achievable. Then, the devices availables for the selected user will appear (Fig. 3.9).

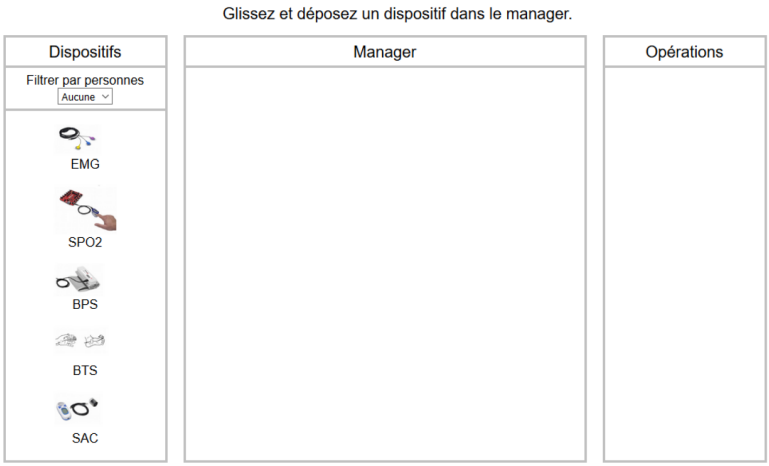


Figure 3.9: DSL Main Menu

- When a device is placed on the manager, the different operations which are available for it will appear. Additionally, depending on the operation that has been selected, several options will be displayed in order to select a suitable means for the calculation. In this case, the EMC device icon has been dragged into the manager window. Then, the operations are displayed on the right side of the DSL GUI (Fig. 3.10).

- Once the previous step has been completed, it will be possible to select the parameters for the calculation. For the EMC device case, the operations parameters appear on the DSL GUI, after the selection of the operation has been made (Fig. 3.11).

- Next, it will be necessary to set the operation according to the calculation method that has been chosen. In the proposed example, the selection of time slots have been carried out for the EMC device

- When all the choices have been made, a summary will be shown on the DSL manager interface; right where the parameters were previosly displayed. Next, it is important to validate the choices that have been made. The selected settings for the presented

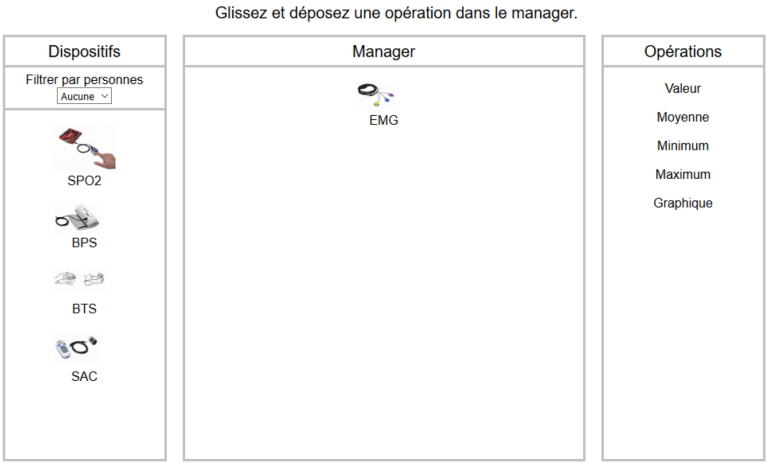


Figure 3.10: DSL Display of operations

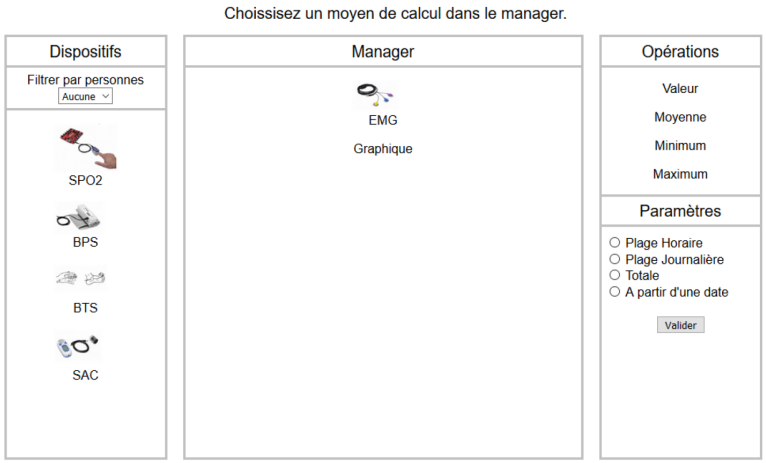


Figure 3.11: DSL Display of parameters

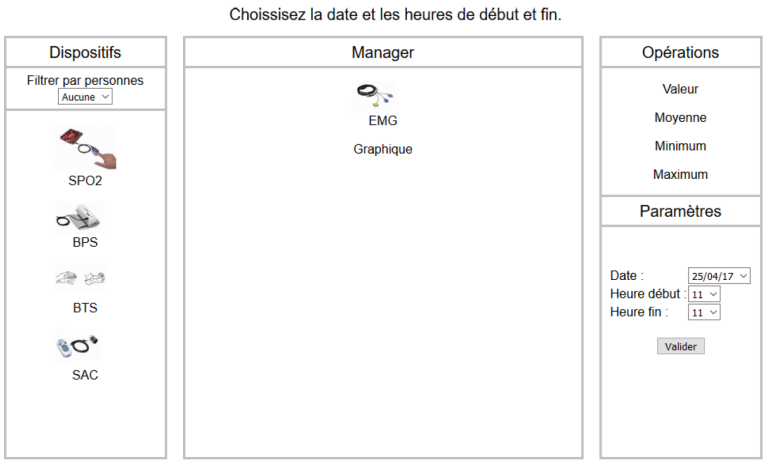


Figure 3.12: Selection of time slots

example are displayed on the DSL GUI. It is possible to distinguish that a period of time comprehending a lapse of two hours has been established. Then, it is necessary to confirm by clicking on the "validate" button (Fig. 3.13).

- After validation, results will be shown on the DSL manager, which will allow the user to

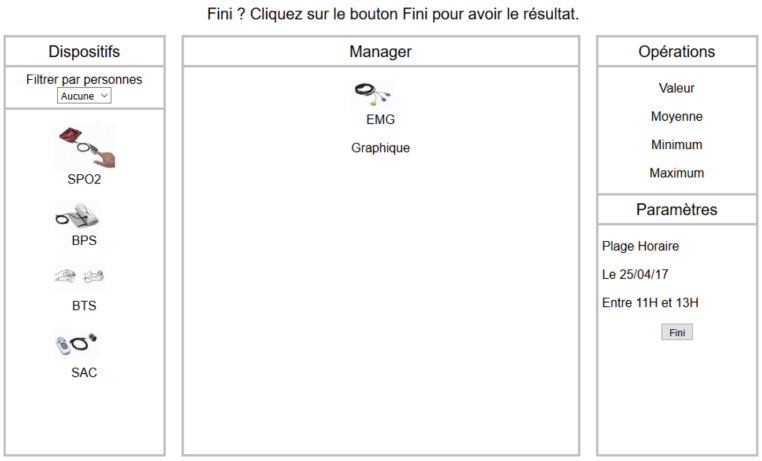


Figure 3.13: Choice of time slots

keep track of the manipulations that have been performed. Additionally, the manipulations are avalaible as textual specifications (Fig. 3.14).

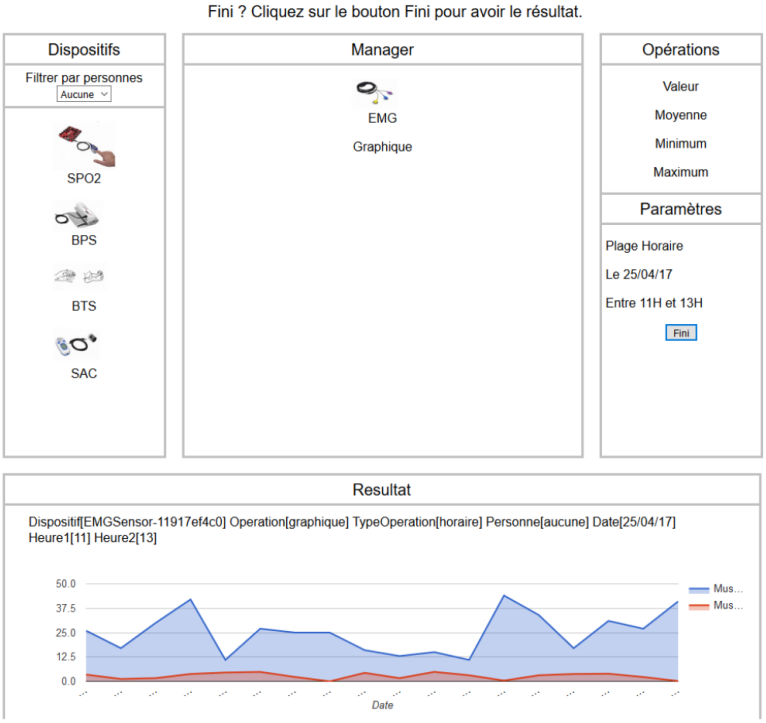


Figure 3.14: Display of results

- Textual specifications are composed by four main elements: (*i*) the name of the device; (*ii*) the operation; (*iii*) the calculation means; (*iv*) tghe selected person. The textual information present in the result can be saved (for example: in a text file) in order to be reused and thus; to find the result without carrying out all the manipulations; allowing its reusability by different applications, thus, not being limited only to the AGGIR variables (Fig. 3.15).

Since in the proposed DSL, the need to represent activities performed by the elderly or handicapped people within a home environment is present; it is imperative to be aware when



Figure 3.15: Saving of results

such an activity takes place, as well as if there exists repetition or periodicity during the interval of its performance. By implementing such a methodology, the detection of anomalies on the behaviour of the inhabitants is intended, so coherence of the activities on their daily living can be ensured.

Spatio-temporal event conditions. In order to deal with temporal constraints, spatio-temporal event conditions are also represented by the DSL. Those are defined by temporal operators such as "*Before, During, After, Begin, End*", and those defined using spatial operators i.e., "*Inside, Outside, Joint*". The proposed criteria to determine the parameters for the example of the precedent paragraph, are: time and space, and within the time dimension. Also, it is relevant to consider:

i) Concurrency: for recognizing activities which take place simultaneously, but they do not necessarily require the user's interaction at the same time. That is, activities that have been started but not yet ended by the inhabitant [64].

ii) Precedence: for establishing a logical order of the activities, i.e., going to the bathroom, and then washing his hands.

iii) Simultaneity: for identifying which activity takes most of the time from the user, when multitasking capabilities might be present, i.e., preparing meal and calling on the phone; or watching television while eating.

iv) Recurrence: for determining a logical sequences of situations. In the case where there is a recurrence of an activity, it is essential to define at what this activity is carried out regularly.

Some examples of these four latter are presented on Fig. 3.16.

So far, the main characteristics of the proposed DSL have been introduced. Subsequently, the explanation regarding the orchestration for both atomic (section 3.3.1) and complex event detection (section 3.3.2) is provided.

3.3 Representation of the AGGIR variables

3.3.1 Atomic Event Detection

Once explained the type of employed sensors and their attributes; as well as the main characteristics of the DSL; the description concerning the recognition of ADL's is carried out in the present section.

An atomic event is defined as an event that can be detected using one reading from a sensor. In order to recognize an atomic event, it is required to evaluate a given sensor reading against a predefined condition from a simple activity. In the proposed approach, an atomic event is simply defined as an ***Activity***, and each ***Activity*** represents one of different tasks composing every AGGIR variable.

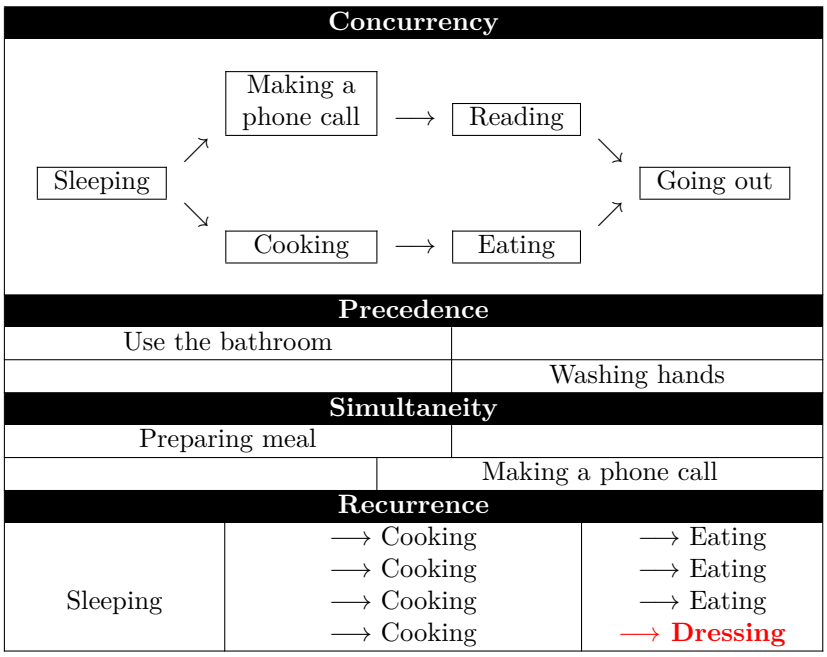


Figure 3.16: Criteria proposed over the time dimension

For the purpose of exemplifying the description provided in the previous paragraph, Table 3.19 shows how each ***Activity*** is associated to data obtained from sensors located within the smart-home environment concerning three of the AGGIR variables: toileting, dressing and transfers. For the toileting AGGIR variable, three atomic events extracted from sensor readings are considered: the bathroom door sensor identifies the ***Activity*** regarding opening/closing the door; the toilet flush sensor indicates the ***Activity*** of activating the toilet flush; and the whashbasin proximity sensor describes the ***Activity*** of washing hands.

Table 3.19: Orchestration of activities

Toileting	**Dressing**	**Transfers**
Activity = $\sum(+)$ Sensor data		
Bathroom door sensor (*On–Off* / `Boolean`)	Wardrobe door sensor (*On–Off* / `Boolean`)	Bed capacitive sensor (*On–Off* / `Boolean`)
Toilet flush sensor (*On–Off* / `Boolean`)	Wardrobe proximity sensor (*On–Off* / `Double`)	Chair capacitive sensor (*On–Off* / `Boolean`)
Washbasin proximity sensor (*On–Off* / `Double`)		

In the next section, details regarding the orchestration of the detection of complex events, are explained.

3.3.2 Complex Event Detection

Subsequent to the description of atomic event detection, it is important to emphasize how complex event detection takes place in the proposed approach. For this subject, parting from readings from sensors defining a simple activity; a complex event can be considered as a sum of multiple events connected together representing each one of the AGGIR grid variables. That

is, an event that summarizes, represents, or denotes a set of atomic events (Activities). In the proposed approach, a complex event is stated clearly as a ***Situation***.

In order to illustrate the composition of a ***Situation***, Table 3.20 indicates how three of the AGGIR variables are composed: (i) the toileting ***Situation*** is composed by the ***Activities***: *open bathroom door*, *use of toilet flush*, *wash hands*; (ii) the dressing ***Situation*** is composed by the ***Activities***: *open wardrobe door*, *spend time changing clothes*, *close wardrobe door*; (iii) the Transfers ***Situation*** is composed by the ***Activities***: *lying down*, *sitting down*, *getting up*. Furthermore, concerning the achievement of each one of the aforementioned variables, the activities conforming such variables must be detected by following a specific sequence: one activity must be finished before the next one can be performed. That is, the precedence criteria must be considered in order for the variable to be completed; as pictured on Fig. 3.16.

Table 3.20: Orchestration of the AGGIR variables

AGGIR Variable = Situation		
Toileting	**Dressing**	**Transfers**
Situation = $\sum$(+) Activities		
Open bathroom door	Open wardrobe door	Lying down
Use of toilet flush	Spend time changing clothes	Sitting down
Wash hands Close bathroom door	Close wardrobe door	Getting up

After describing the mechanism for orchestrating complex events; in subsection 3.3.3, the proposed operators describing the DSL are introduced.

3.3.3 Proposed operators

Allen's temporal operators

In order to deal with constraints regarding the time dimension, it is necessary to express conditions regarding temporal relations between sensor states, which are relevant for describing activities. To this end, the DSL takes advantage of the criteria over the time dimension precised on section 3.2.3, and illustrated on Fig. 3.16: concurrency, precedence, simultaneity, recurrence; i.e.; the event outlining that shower is on during presence in the bathroom; detects an activity described between two sensors. For this purpose, a useful tool for representing temporal conditions between two time intervals are the Allen temporal relations [6] (Table 3.6).

With the aim to establish finite time intervals, temporal bounds to the Allen's temporal relations were applied; e.g. the constraint X *MEETS* $[t_1, t_2][0, \infty)$ Y implies that Y should be *met by* X, that the start time of X must occur between t_1 and t_2; and that the end time of X should occur right before the beginning of Y.

Fig. 3.17, 3.18, 3.19, 3.20, 3.21; present an example of how temporal conditions can be used to model activity recognition in our approach, alongside with location based operators; which are presented in the next paragraphs.

Location based operators

Location based operators are in charge of helping determine the position of the inhabitant within a home environment; as well as the description of ADL's through sensor readings. To this effect, the proposed approach considers location based operators: "*Inside*", "*Outside*" and

"*Joint*"; in order to locate in space the ADL's performed for the inhabitant. The description regarding each one of the proposed location based operators are presented on Table 3.21.

Table 3.21: Location based operators

Operator	Description	Data type
Inside	Returns true if the user is inside a given area.	String
Outside	Returns true if the user is outside a given area.	String
Joint	Returns true if the user is in two locations at the same time	String

Next, for the purpose of dealing with planned tasks that need to be performed by the inhabitant, event based operators are introduced.

Event based operators

Additionally, with regard to determination of planned tasks that should be carried out by the inhabitant, such as taking medications; event based operators are important for this matter. Those operators are presented on Table 3.22.

Table 3.22: Event based operators

Operator	Description	Data type
Planned task (medical measurements)	Returns true if the user performs a planned task	String
Unplanned tasks (medical measurements)	Returns true if the user performs an unplanned task	String

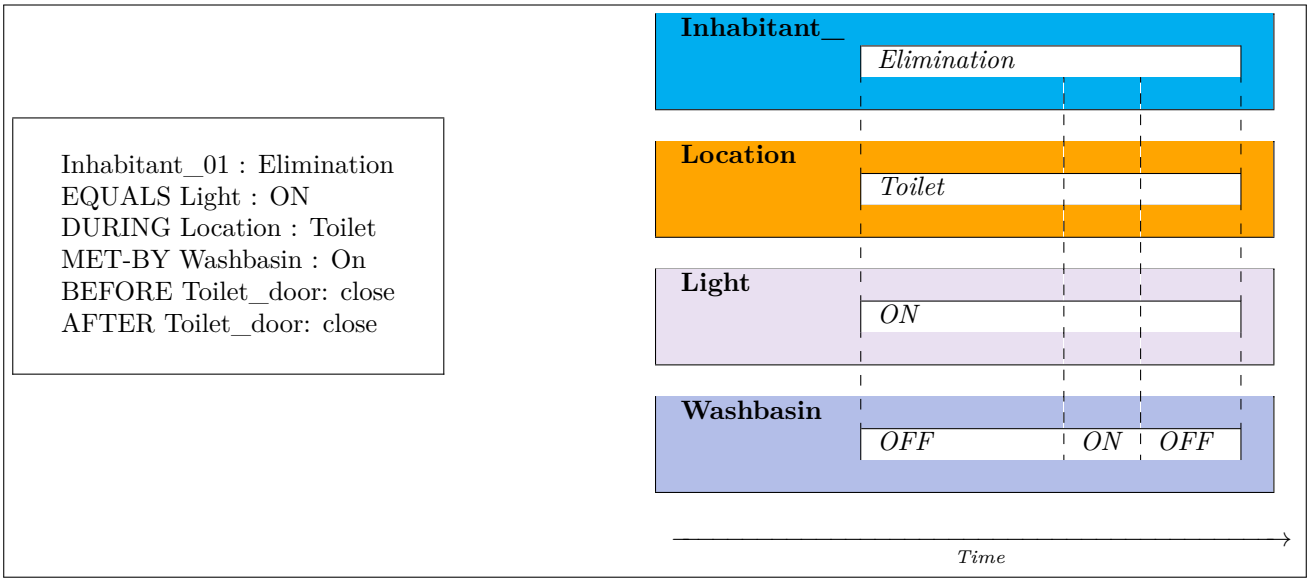


Figure 3.17: Elimination

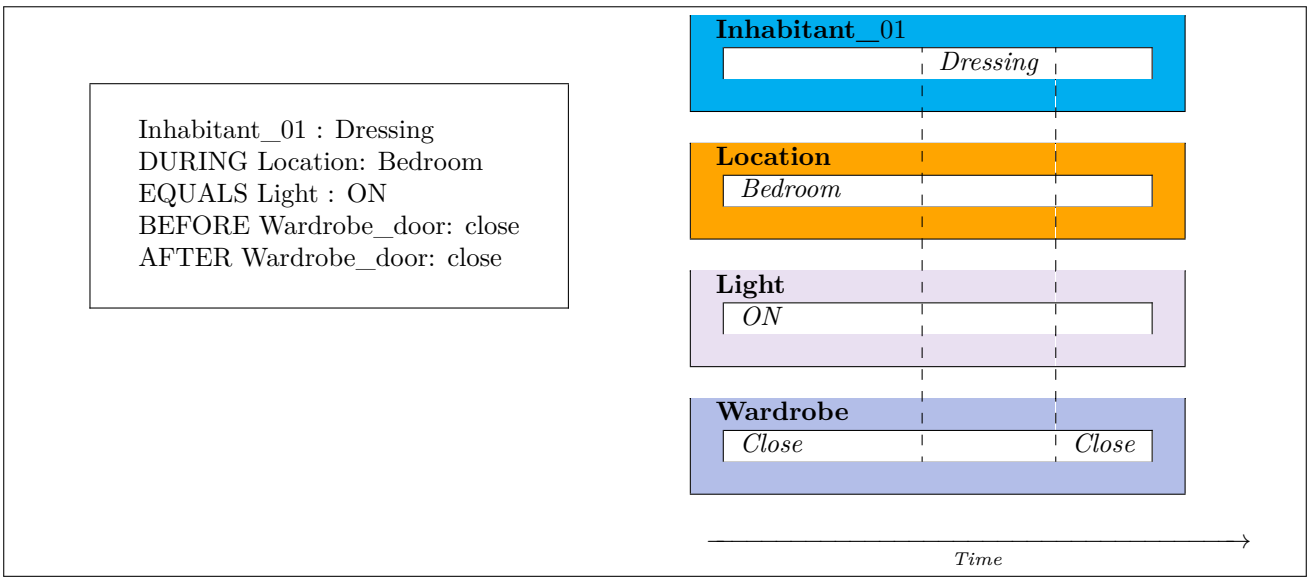


Figure 3.18: Dressing

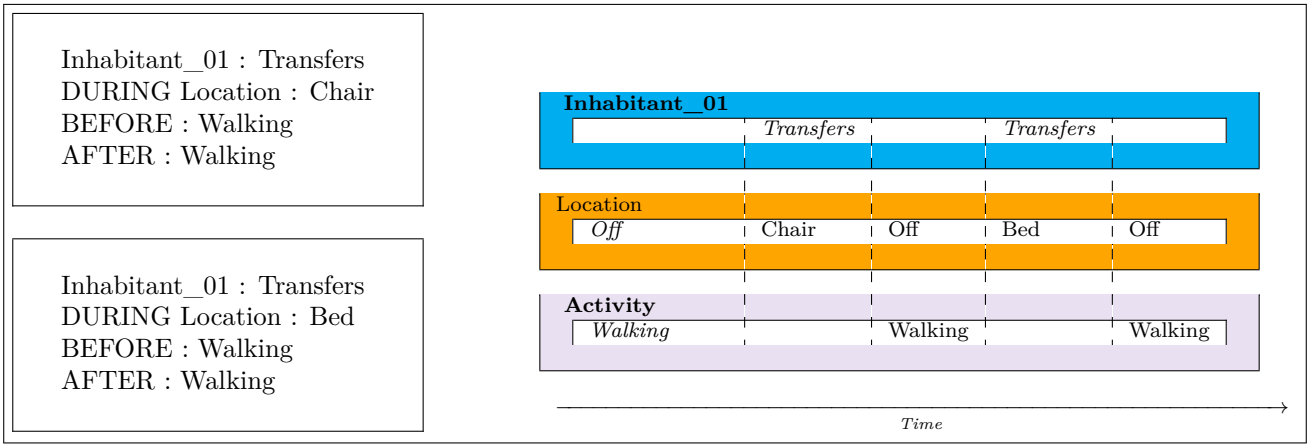


Figure 3.19: Transfers

3.4 Conclusions

In this chapter, a review of the state of the art is introduced, in which authors implement spatio-temporal operators and logic languages as their main contributions. In addition, a proposal for a Domain Specific Language (DSL) is presented, by means of spatio-temporal operators in order to be able to manage time and location of activities; as well as event detection limitations. the DSL proposal is aimed at describing activities carried out by a subject within a smart home environment and to identify the AGGIR variables. The chapter 4 is dedicated to the presentation of the framework proposal for the validation and experimentation of the DSL.

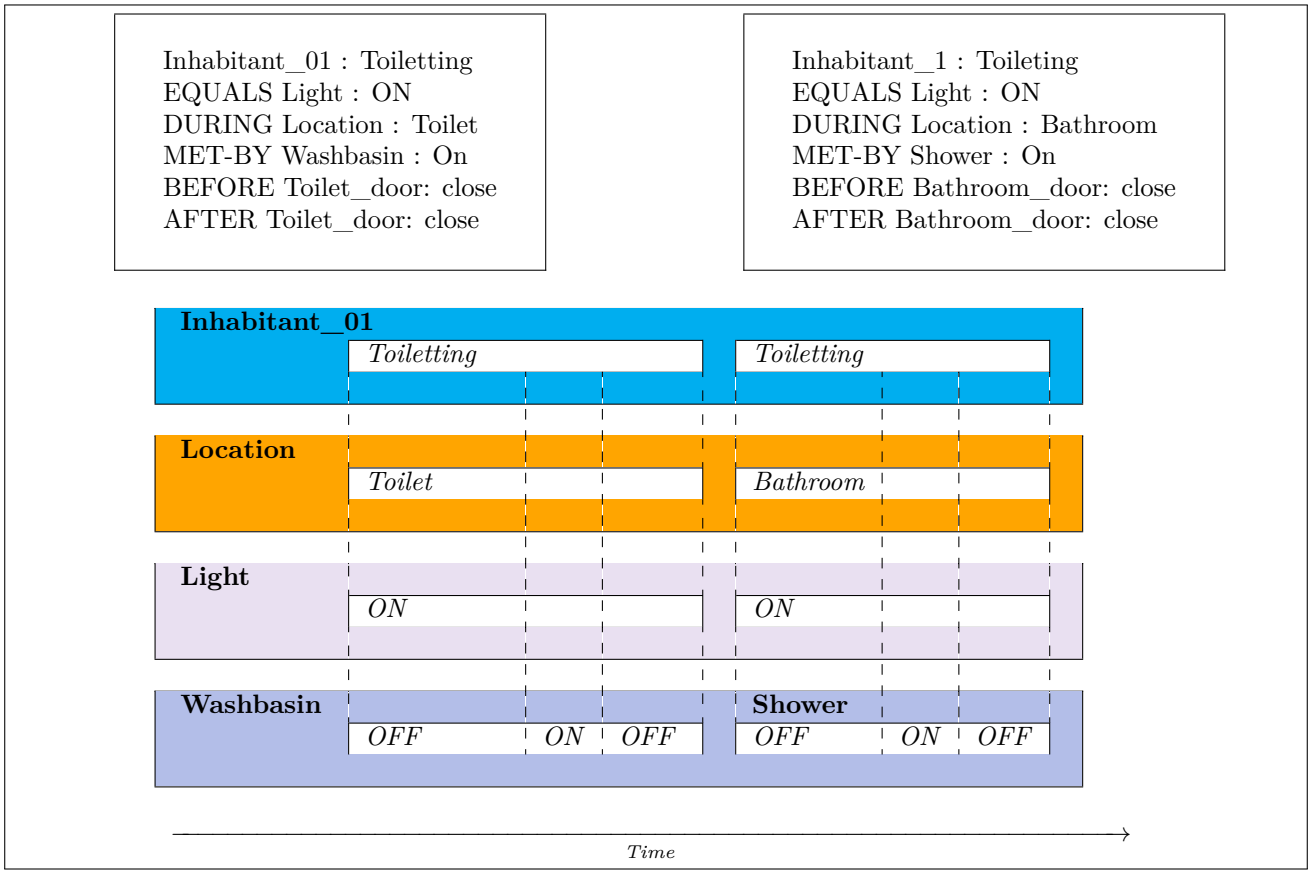


Figure 3.20: Toileting

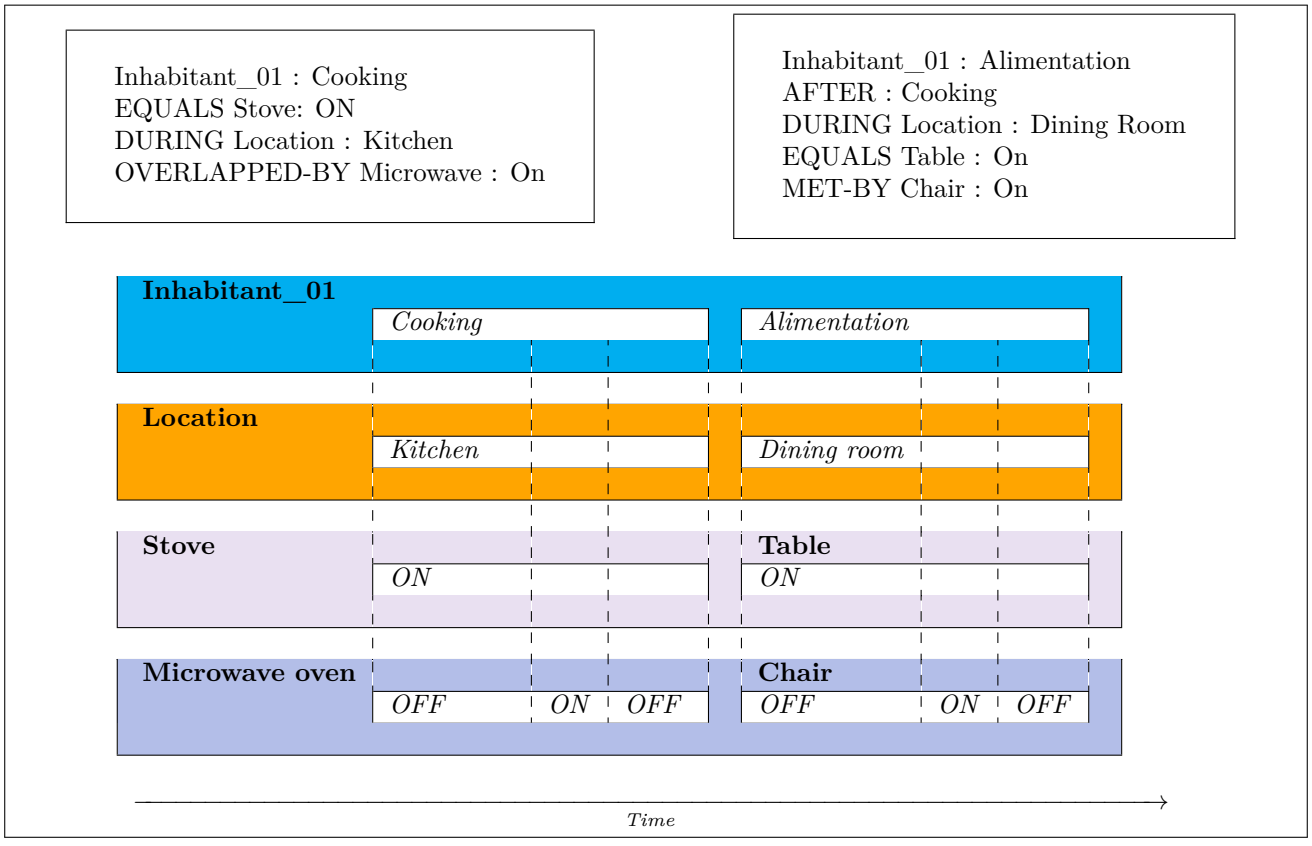


Figure 3.21: Alimentation

Chapter 4

A Framework to Evaluate the AGGIR Variables: Our Approach

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Subsequently to the proposed DSL, a framework is introduced to fulfill the requirements for processing complex events regarding the AGGIR grid model generated by data recovered from sensors within a smart home environment; in order to evaluate the level of independency of elderly people, according to their capabilities of performing activities and interact with their environments over the time. This chapter is dedicated to the description of the general architecture of the aformentioned framework. Additionally, each component of the framework is explained in detail in sections 4.1.1, 4.1.2, and 4.1.3, respectively.

4.1 Framework Modules

The main purpose of the presented framework is to encourage users who are not necessarily acknowledged in the programming field to be able to define events according to the AGGIR grid variables; by providing a high-level abstraction, which makes it easy and intuitive by means of concepts that are close to the final users.

As previously mentioned, the proposed framework is composed by three main modules, as shown on Fig. 4.1:

(i) the *Simulator module* (section 4.1.1),

(ii) the *Descriptor module* (section 4.1.2),

(iii) the *Analyzer module* (section 4.1.3)

All of them are supported by the DSL. A brief description of each one is provided in the next paragraphs.

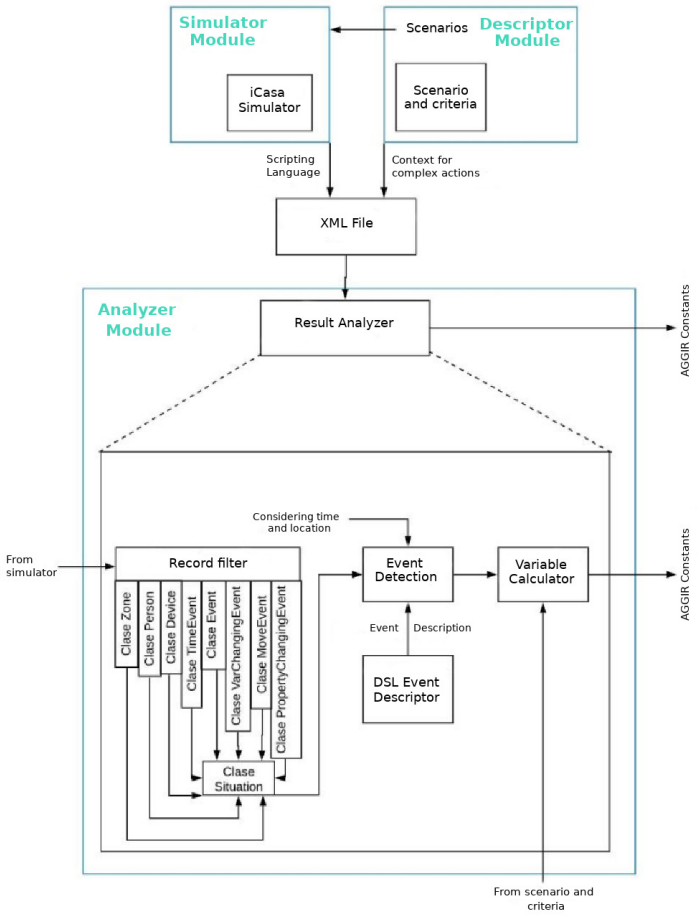


Figure 4.1: General Architecture of the proposed framework

4.1.1 Simulator module

In order to describe the elderly's ADL's, smart-home environment scenarios need to be parameterized. For this purpose, the activities performed by the subject are carried out and information is recovered from sensors located within the smart home environment. As the Simulator module, iCASA [95] was integrated to the proposed framework, which is a smart home simulator which allows to have control over: time, environment, inhabitants, devices, a graphical user interface, scripting facilities (for the environment), and notication facilities [96], as enlisted on Table 4.1. iCASA is used in order to set up a simulated scenario.

The purpose of employing iCASA, which is based on OSGi [7] and iPOJO [46], is that it takes advantage of the versatility and dynamism of the two latter, which are provided as a set of modules and components (e.g. bundles and iPOJO components) that are deployed on a OSGi/iPOJO framework.

Next, the main features of the Descriptor module are introduced.

4.1.2 Descriptor module

For the purpose of helping users to interact with the framework, the Descriptor module provides a Graphic User Interface (GUI), in order to describe all the criteria over the time dimension, location, and events, as well as the required scenarios for the simulation. Also, sensors to identify the ADL's have to be specfied through the GUI. A group of sensors that can describe

Table 4.1: iCASA facilities

Time	Possibility to slow down, speed up or stop time during the simulation. Simulation of long-term actions such as energy consumption to skip to important actions.
Environment	Definition of different zones in a house. An administration interface to modify different physical properties (temperature, luminosity, etc.) of the different zones, is provided.
Inhabitants	Insertion or removal inhabitants from the environment. Inhabitants, can move from zone to zone, may be carrying physical devices.
Devices	Devices can be simulated or real. At any time, the user can add or remove new simulated devices and modify their localisation in the rooms.
A graphical user interface	The interface displays a map of the house and the localisation of the different devices. It allows to create and configure devices, create and move physical users and watch their actual configurations.
Scripting facilities	Support to the scripts writing to control the environment. Scripts provide a convenient way to test the applications under reproducible conditions.
Notifications facilities	iCASA is event-based and is able to notify subscribers of any modifications in the environment.

such activities are introduced on Table 3.16.

With regard to the scenario specification concerning a certain period of time, the descriptor module is in charge of the definition of the parameters with respect to location of both ADL's and sensors, type of sensors, time, and events that need to be identified:

Location Map: It is applied to refer to the representation of the environment by means of the house plan where the implementation of the sensor network takes place.

Sensor network. It is focused on defining information related to the sensor network environment infrastructure. To this end, relevant data should be managed, such as: the inventory of sensors located within the smart-home environment, as well as the location where each sensor is implemented.

Sensor reading. Due to the fact that information retrieved from sensors are in a raw format, such data need to be organized for the purpose of easing their retrival and interpretation during the event detection process.

Event condition. Since conditions are established for triggering the detection of events, such conditions must be defined by the user.

Event ocurrence. Once the event conditions have been provided, the event ocurrence must be managed in accordance with such aforementioned conditions.

The analyzer module is explained in detail in the next section.

4.1.3 Analyzer module

In order to recover data from the Simulator module and the Descriptor module; the Analyzer module is proposed to carry out such a task. Once all the necessary data is collected, the analyzer module analyzes them in order to classify them and evaluate if the AGGIR variables of the case study have been carried out to completion. The Analyzer module consists of:

Record filter

Once the simulation has been conducted, in order to manage the obtained data, the record filter of the Analyzer module separates the recover data into a series of records. Each record is risponsible of the description of actions collected by the sensor network located within the smart-home environment. Therefore, each register is conformed by data fiels, i.e., the time when the action takes place (corresponding to the simulator clock), the sensor ID, and the sensed value. Furthermore, because of the retrieval of such values is generated in raw data format, it is necessary to translate them by means of the Analyzer Module with the aim of achieving the identification of events, as well as calculation of values related to the AGGIR grid variables.

With the aim of performing a filtering of all entries, the first task of the analyzer module is to classify such inputs in a correct manner. For this matter, the generation of "filters" was modeled in the present approach as classes. These latter were introduced in order to determine the type of elements that integrate the analyzed set of instructions, by giving each element the appropriate attributes for the modeling of raw data.

To this extent, the proposed generated classes for data classification are:

Clase *Zone*: for modelling the simulator zones; in charge of identifiers, measurements, variables and their values.

Clase *Device*: for managing several aspects concerning the simulator devices; i.e. identifiers, properties, values spatial location.

Clase *Person*: in charge of controlling the inhabitants within the smart-homme environment; such as the person identifiers and their location with respect to the simulation context.

Clase *TimeEvent*: for modelling the instructions with regard to the time dimension. That is to say, parting from time raw data, it is possible to generate real time data allowing time management during the analysis.

Clase *Event*: considered as a basic event, in order to model situations that do not require additional data.

Clase *MoveEvent*: subclass of the *Event* class. It is in charge of of modelling events regarding movement within a specific zone in the smart-home area, either a person or a device.

Clase *VarChangingEvent*: subclass of the *Event* class. It is used for modelling events concerning modificactions to assignated variables to a specific zone, i.e. temperature change.

Clase *PropertyChangingEvent*: for modelling events that generate modificatios with regard to intrinsic properties of the simulation devices.

Clase *Situation*: for modelling complex situations. Complex situations are a result of the interaction of several atomic events which allows to identify abnormal behaviour.

Subsequently, in order to detect the performed activities, the *Event detector* is presented.

Event detector

After all relevant data from WSN's and BSN's have been gathered, the identification of events must be carried out. To this extent, the Event detector relies on the introduced DSL to achieve such identification, by managing information grouped in multiple records which are extracted from several sensors

With the aim of separating each reading detected by several devices, the Event detector retieves information in terms of the scripting language. Such events are identified as low-level actions instances; e.g., if a presence sensor is off in room X, and after a period of time another presence sensor is on in room Y; it can be inferred that the action "walk" was carried out.

Regarding the recognition of malfunctions, the detection of abnormal situations is carried out at the level of identification of events and situations. For this matter, throughout the analysis of low-level events (i.e. situation class instances) collected from device readings from the simulator module script, it was possible to extract a set of anomalies to be detected by the aforementioned module. Such anomalies are enliste hereafter:

FloodSensor detected a problem: For the purpose of identifying if there exists a leak or break in pipelines, the flood sensor will be on. Additionally, the occurrence of floods may certainly indicate an issue for the inhabitant.

DimmerLight exceeded MAX time ON: It occurs when the dimmer lights are on during a period longer than ten hours. For this matter, it is assumed that leaving lights on when no needed may implicate a higher energy cost, besides lack of attention with regard to daily tasks; as well as a location problem.

BinaryLight exceeded MAX time ON: Similar circumstances as the previous paragraph. In this case, the problem is triggered by an indicator detailing either the device is on or not.

Heater exceeded MAX time ON: It is identified when the heater device has been on during a period of time longer than twelve hours. Additional to the high energy input, it can represent an abnormal thermal sensation, neglect by the inhabitants; as well as location problems.

Cooler exceeded MAX time ON: Similar to above, but with regard to the cooler device.

Not getting out of a room for long time: Such an anomaly is identified when a resident stays in his room for a period of time longer than four hours (not considering sleeping hours). Given to human nature, in order to guarantee a healthy well-being, it is necessary to use the toilet or drink water on a relatively regular basis. Moreover, entertainment plays an importan role for this matter as well. The fact that the inhabitant does not leave his room could be translated as a location problem, the lack of good housekeeping, alimentation and elimination problems, as well as experiencing difficulties with leisure activities.

Possible accident in ZONE: This abnormality is triggered when an inhabitant stays still in one zone of the hose (except for rooms, which are treated in the previous point). To this extent, maximum periods per length of stay were established for each one of the possible zones. If the time limit is exceeded, it can be inferred that there exits location problems, lack of coherence behaviour, tranfer difficulties, as well as disregard of domestic responsibilities.

Heater is ON when no needed: This concern appears when the heater device in on and the actual temperature measurement of the zone does not require such a device to be on. The latter can be interpreted as neglecting of the household tasks, location problems and coherence issues.

Cooler is ON when no needed: Same case as the above-mentioned situation, but concerning a cooler device.

High CO concentration: According to NIOSH (National Institute for Occupational Safety and Health)[2], a prolonged exposure (4.000g/m^3) to high concentration (4.000g/m^3) of carbon monoxide (CO) (ten hours on average) could be hazardous to human health; it should not happen more than once a year. Moreover, a short exposure time (seconds) to concentration levels around 1.375g/m^3 is considered as a threat to human life. The presence of the latter is detected by the CO concentration sensor, and it can be related to problems with performance of household tasks; i.e. impossibility to check on the status on pipelines.

High CO_2 concentration: Same anomalie as the previous paragraph, but concerning a high concentration (9.000g/m^3) of carbon dioxide (CO_2) (ten hours on average). Additionally, a exposure time to concentration levels around 54.000g/m^3 for longer than fifteen minutes endangers people's health; and a brief exposure to a concentration level of 72.000g/m^3 is considered as a threat to human life.

Main door LEFT OPEN for a long time: Due to the fact that keeping the door open may involve either an accident when leaving the house or a distraction; this issue can be evident whenever the door is open for a long period of time; implying location problems, lack of both coherence and maintaining the household.

Siren ringing: Even though the siren device does not present a funtioning asociated with any emergency in the simulation; it must be assumed that if such a device is on, the residents must leave the house. Therefore, the recognition of this incident may be related to difficulties on the maintenance of the home.

Irregular urination time: With the purpose of identifying whenever an inhabitant presents a reduced urination frequency, this event is recognised if the individual does not carry out his toileting, either by exceeding a lapse of four consecutive hours; or not toileting at least six times a day during a period of time of twenty four hours. The detection of this problem takes into account constraints with regard to elimination, personal wash, alimentation (lack of clean water) and tranfers.

Not changing clothes: In order to detect an anomaly associated with dressing difficulties, this incident relies on the condition of not opening the wardrobe at least once a

[2]https://www.cdc.gov/niosh/index.htm

day (twenty-four-hour period); which can be translated as a complication for dressing as well as a lack of coherence. Also, it can suggest the abscence of proper toileting.

Lights ON at a wrong time: With the goal of monitoring the home lighting of the enviroment during sleeping hours (from 12:00:00 a.m. to 5:59:59 a.m.), this problem is identified whenever the light devices are on during the aforementioned time lapse. Furthermore, this issue may represent a determining factor with regard to the performance of home care, self-location, and coherence; besides an unnecessarily high consumption of energy.

Wandering around at a wrong time: Due to the fact that the presence of motion during sleeping hours (from 12:00:00 a.m. to 5:59:59 a.m.), taking place in different house areas other than the bedroom (such as the toilet or the house corridor) may seem strange; this issue is detected whenever the above-mentioned constraints are met. Moreover, this restriction may indicate both location problems and lack of coherence.

Abandoning kitchen while cooking: In order to detect anomalies concerning the inhabitant leaving the kitchen area after started cooking; firstly movement inside the kitchen area alongside an increase of temperature must be recognised; secondly, the absence of motion within the aforementioned area for a period of time longer than fourty five minutes must be identified. In addition, this event may point out location problems, coherence issues, as well as lack of household tasks.

Each one of the above-mentioned anomalies is related to the AGGIR grid variables. The detection of any of these issues may return a negative value for the associated variable, that is to say, the inability to satisfactorily carry out the AGGIR cariable in question.

Next, and explanation with regard the variable calculator of the analyzer module is provided.

Variable calculator

Regarding the achievement of the AGGIR variables, criteria consisting on accomplishing a determined number of events during a specific time lapse related to the evaluated AGGIR variable must be fulfilled; e.g., in order to validate if the dressing AGGIR variable is consummated, AGGIR dressing event conditions such as moving towards the wardrobe at least twice a day must be met. For this purpose, although every AGGIR variable is based on three major states, which identify that the elderly inhabitant possesses the ability to perform the ADL's conforming a specific variable, whether it is completely, partially, or not existent at all; this study covers a proposal which only relies on two cases out of the three abovementioned options; meaning that either the inhabitant is in complete possession of the skills concerning the perfomance of the the ADL's composing the evaluated AGGIR variable or simply not.

In the next section, the process how the aforementioned modules interact with each other for achieving the detection of complex events is explained.

4.2 Complex Event Detection

Provided the main components of the aforementioned framework proposal, the description of the process for achieving the detection of complex events is then referred.

Due to the fact that ADL's take place within a domestic surroundings, sensors for detecting such ADL's are placed within a smart-home environment. For this matter, such an environment is defined and configured through the Simulator module. Then, the detection process is

triggered by the readings obtained from the sensors located within the smart home environment simulator.

In order to obtain information to achieve the identification of the AGGIR variables after every activity has been carried out to completion, some relevant data have to be considered, e.g. *startTime*, *endTime*; as shown in Table 3.17. All these data are specified in the Descriptor module. After the simulation took place, a history log file is created, which considers the logical aspect of situations, i.e., if the inhabitant is eating and its noon, it might seem logical, but the fact that the inhabitant is eating in the toilet is not logical.

As a result, the history log file is necessary to deduct the possible activities which will be performed in the future, and to find a relationship among them to assure a coherent behaviour. Such a file will permit to obtain information whether it is from long or short periods of time; making possible the identification of complex situations inside the home environment such as alimentation, toileting, transfers, etc.; where data collected through the timeline of activities is useful to determine if the behaviour of the inhabitant can be considered as normal.

4.3 Discussion

A proposal relying on a mechanism which allows a framework to integrate all the atomic event detection, and complex event detection tasks, as well as the processing of data referred to the recognition of the AGGIR variables, is presented. Moreover, such a framework introduces three main modules in order to manage all the tasks that are related to processing complex events within a smart-home environment: (i) the Simulator module, (ii) the Descriptor module, and (iii) the Analyzer module.

The introduced framework is intended to describe activities performed by a subject within a smart home environment and to identify the AGGIR variables.

In the next Chapter, the description of several use cases is introduced, where the simulation methodology is highlighted; as well as the experimental results which were obtained.

Chapter 5

Prototype and evaluation

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5.1 Introduction

In this chapter, in order to evaluate the performance of the Domain Specific Language proposed in the previous chapter, a set of experiments is presented. Additionally, a full description of the simulation methodology regarding the proposed framework with all technologies under use is provided. For this matter, several case studies concerning ADL detection are introduced with the purpose of highlighting the benefits and limitations of the introduced approach, aimed to monitor the elderly at home.

5.2 Use Case Description

Examples of use cases are important for demonstrating the efficacy of the proposed DSL. For this matter, a set of experiments with regard to the detection of the AGGIR grid variables is introduced. Furthermore, with the aim of describing the simulation methodology, the simulation steps as well as the results obtained from experimental simulations are outlined.

5.2.1 Simulation Methodology

In order to detect either the achievement or absence of the AGGIR variables by means of the proposed DSL, the methodology for the experimental simulations carried out in the present approach is reviewed in this section. To this extent, the steps for performing such simulations are indicated by a set of instructions that are enlisted and explained in detail, in which, remarks about the importance of the proposed criteria over the time and location of activities, type and location of sensors, as well as events that require to be detected, are precised in the next

paragraphs. Similarly, the manner how each component of the framework intervenes to obtain the simulation results is described hereafter.

For the purpose of evaluating the introduced DSL, four of the AGGIR variables (i.e., dressing, toileting, transfers, and alimentation) were picked with the aim of determining their testability in many scenarios, by means of records representing the occurrence of ADL's performed the elderly inhabitant within a one-week period.

The simulation steps for the proposed framework are described in the next paragraphs:

Step 1. In order to prepare the scenario for an elderly indoor daily routine over the course of one week, the first step consists on the specification of the the criteria over the time and location of activities, type and location of sensors, and events that have to be detected; in this specific case, all activities related to the dressing, toileting and transfer AGGIR variables. For this matter, the aforementioned actions are carried out in the GUI of the Descriptor module. To this end, the primary source of information used to generate the scenario is the schedule proposed by the work of [192]. However, in order to make the scenario more suitable for the simulation, many modifications take place. Furthermore, for the purpose of making the scenario more suitable for the simulation, the XML format is used to describe the scenario programmatically, given that such files allow to define events chronologically; thus facilitating the processing carried out by the Simulator module.

Step 2. Once the information provided by the Descriptor module is established; the Simulator module, i.e., the iCASA framework, executes the simulation according to such precised information.

Step 3. After the simulation is performed, the record filter component of the Analyzer module organizes the resulting data into a set of records, each of which represents an action captured by a sensor within the smart home environment (Fig. 4.1). To this end, each record consists of data fields, such as the time it occurred (according to the simulator clock), the sensor ID and the sensed value. Moreover, due to the fact that such values are raw data, they must be interpreted by the Analyzer module in order to generate the detection of events and then calculate the values of the AGGIR variables. Subsequently, having collected all the results, the next step is the detection of events. For this purpose, an event is considered as a composite act that is described by data provided by several sensors; that is to say, an event relies on more than one record in raw data. Afterwards, the DSL is in charge of providing an accurate and unified description of the events. Once the event detection has occurred, the aim of the variable calculator within the Analyzer module is indicating whether an AGGIR variable has been accomplished or not.

In the present section, the simulation steps ragarding the evaluation of the AGGIR variables have been presented. In order to test the proposed apprach, their aplication to several case scenarios is required. For this matter, experimentation aimed at analyzing different use cases is provided hereafter.

5.2.2 Experimental Results

So far, the methodology criteria employed for the simulation has been explained. Next, it is necessary to implement such criteria to different simulation scenarios. For this purpose, two main cases are considered: (i) First scenario, consisting on ideal week case scenario, in which all the ADL's related to a specific AGGIR variable performed by the inhabitant are conducted sucessfully; (ii) Second scenario, with regard to the generation of a failure on the daily routine of the inhabitant, by ramdomly dropping some of the ADL's conforming a specipic AGGIR variable.

Moreover, in order to generate the required simulations, the aforementioned scenarios consist on two sets of inputs managed by the proposed framework. Each one of such scenarios is conformed by seven days (one-week period).

In what follows, the main characteristics of the simulation scenarios concerning the identification of ADL's as well as the AGGIR grid variables are described. Furthermore, close attention is paid to the results obtained after each simulation has been carried out.

In addition, since it is required to evaluate the ability of the proposed approach to deal with larger time domains, as well as several records and events; the scalability of the introduced framework is also illustrated.

Alimentation AGGIR variable

Provided the simulation methodology, with the aim of evaluating the alimentation AGGIR variable, a use case case description regarding such a variable is introduced by two simulation scenarios, as stated on section 5.2.2. Moreover, certain requirements must be fulfilled for the proposed scenarios. That is to say, for the first scenario, the ADL related to cooking must be performed by the inhabitant before the alimentation AGGIR variable takes place, That is to say, the accomplishement of preconditioned events conforming the cooking activity is necessary; more particularly: (i) open/close the refrigerator door; (ii) open/close the kitchen cabinet door; (iii) use of the stove/burners; (iv) use of the traditional/microwave oven; not necessarily in that order. Whereas, as for the second scenario, some of the abovementioned events concerning the cooking task were dropped. For this matter, information collected from sensors located within the kitchen area must be analyzed. To this end, data originated by both the refrigerator and kitchen cabinet door sensors, the stove magnetic sensor, as well as the oven / microwave oven sensor, must be gathered.

Nonetheless, it is important to remark that according to the AGGIR grid, cooking is not conceived as a discriminatory variable, neither as an evaluation criterion for the alimentation AGGIR variable; which only requires the elderly being capable of serving and eating a prepared meal. For this reason, in our approach, cooking is considered as an ADL which can trigger the Alimentation AGGIR variable, not meaning to contradict the preestablished evaluation criteria, which can also be used for detecting the aforementioned variable in this work.

Once the cooking task is achieved, additionally to the first scenario, events defining the alimentation AGGIR variable must be identified, such as: (i) sitting within the dining room area; (ii) placing meal on the table; (iii) spending time consuming food. Moreover, with the aim of identifying the ocurrence of the abovementioned events, data form sensors located within the dining room area must be collected, such as: chair capacitive sensor, table capacitive sensor, dinig room presence sensor. With respect to the second scenario, some of the ADL's conforming the alimentation AGGIR variable, were arbitrarily left out. Additionally, in order to assure a coherent self-feeding behaviour, both scenarios must occur at least three times a day. The orchestration of activities regarding the alimentation AGGIR variable is illustrated on Fig. 5.1.

Having completed the simulations of both scenarios, results concerning the first scenario proves that, indeed, the detection of complex events conforming the cooking tasks well as those from the alimentation AGGIR variable were carried out to completion succesfully, in accord with to the predetermined input conditions, as enlisted on Table 5.1, in which, check marks are in charge of indicating that the minimum number of detected events related to the aformentioned variable have been performed satisfactorily.

Moreover, as for the second scenario, due to the fact that some of the activities were not taken in account for the analysis of both the cooking activity and the alimentation AGGIR

Cooking
Location: Kitchen
∑(+)Activities
Open refrigerator door
Open cabinet door
Use of stove
Use of oven
∑(+)Sensor data
Refrigerator door sensor (*On-Off* / `Boolean`)
Cabinet door sensor (*On-Off* / `Boolean`)
Stove electromagnetic sensor (*On-Off* / `Boolean`)
Oven electromagnetic sensor (*On-Off* / `Boolean`)

After –>

AGGIR Variable = Situation
Alimentation
Location: Dining room
Situation=∑(+)Activities
Sitting down
Placing meal on table
Spending time eating
Activity=∑(+)Sensor data
Chair capacitive sensor (*On-Off* / `Boolean`)
Table capacitive sensor (*On-Off* / `Boolean`)
Dining room presence sensor (*On-Off* / `Boolean`)

Figure 5.1: Orchestration of the AGGIR Alimentation Variable

Table 5.1: Results of the first scenario

		Cooking	**Alimentation**
No. of events	**MON**	☑ 12	☑ 7
	TUE	☑ 11	☑ 9
	WED	☑ 9	☑ 9
	THU	☑ 11	☑ 8
	FRI	☑ 10	☑ 8
	SAT	☑ 10	☑ 9
	SUN	☑ 9	☑ 7
	Total	☑ 72	☑ 57

variable; the proposed framework also succeded in identifying either the concerned ADL was performed or was not completed according to initial parameters, as presented on Table 5.2.

Table 5.2: Results of the second scenario

		Cooking	**Alimentation**
No. of events	**MON**	☒ 7	☑ 9
	TUE	☑ 10	☒ 6
	WED	☑ 11	☑ 8
	THU	☒ 5	☑ 8
	FRI	☑ 9	☒ 3
	SAT	☒ 7	☒ 5
	SUN	☑ 10	☑ 9
	Total	☒ 59	☒ 48

Furthermore, in order to illustrate the number of events related to the cooking task, as well as for the alimentation AGGIR variable; Fig. 5.2 and Fig. 5.3 introduce by means of a graphical representation the events detected for both scenarios. Additionnaly, it can be observed for each case that the second scenario present a significant threshold with respect to the first scenario in some of the simulation weekdays, which implies that both the cooking activity and the alimentation AGGIR variable were not achieved particularly on those days; and hence, during the evaluated week concerning the second scnerio.

In this section, the alimentation AGGIR variable was calculated with the aim of evaluating

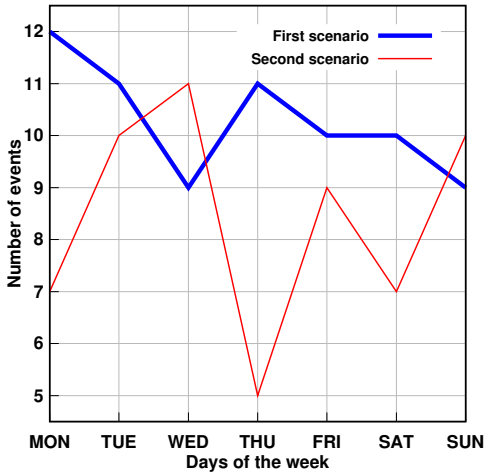


Figure 5.2: Cooking events

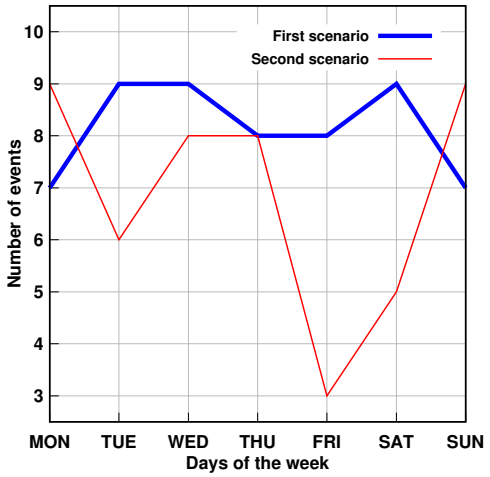


Figure 5.3: AGGIR Alimentation events

the proposed approach. Next, with a view to evaluate a health related scenario, a case with regard to blood glucose measurement is introduced.

Health-care device use case

With the purpose of assessing a practical case study of a planned task regarding the use of a health-care device, two scenarios implicating the deployment of a device for tracking blood glucose are proposed. Moreover, with a view to ensure continous measuring, it is necessary for the house resident to perform such measurements at least three times a day. Additional conditions for the required scenarios are introduced in the next paragraph.

In order to evaluate the scenarios related to the blood glucose level measurement performed by the inhabitant, all the simulations and operations are carried out by the proposed framework by means of records corresponding to each scenario. To this extent, the first simulation scenario consists of week during which the person was completely risponsible of employing a glucometer device for measuring his own glucose levels, meaning that the completion of a planned medical task was achieved. Furthermore, with the aim of causing non-functional conditions, the second scenario was thought to randomly exclude some of the measurements thoughout several days of the week. Results obtained from the simulations corresponding to both scenarios, are presented

in Table 5.3

Table 5.3: Results of the first scenario

		First scenario	Second scenario
No. of events	MON	☑ 3	☑ 6
	TUE	☑ 3	☒ 1
	WED	☑ 6	☑ 3
	THU	☑ 4	☒ 0
	FRI	☑ 3	☑ 3
	SAT	☑ 3	☑ 4
	SUN	☑ 5	☒ 2
	Total	☑ 27	☒ 19

With regard to the simulation results, it can be observed in Fig. 5.4. that the events occured during the simulation week for the first scenario were satisfactorily detected, which implies that the measurement of the glucose level were achieved in accordance with the preset criteria, meaning that the house resident is in charge of planned tasks in a coherent manner. Additionally, information obtained from the second scenario shows that the inhabitant did not succeed in taking charge of a planned task, due to the fact that the number of identified events per day were not performed coherently (three to six times a day); more precisely, tuesday, thursday, and sunday.

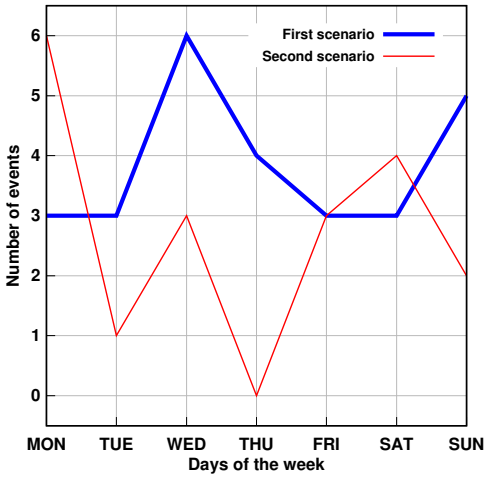


Figure 5.4: Glucose device events

This latter can be interpreted as the efficiency of the framework to perform the recognition of planned tasks concerning measurements carried out by the user by means medical devices. Subsequently, in order to evaluate several AGGIR variables, as well as the scalability of the introduced approach; the toileting, dressing and transfer variables are assessed in the next section.

Toileting, Dressing and Transfer AGGIR Variables

For the purpose of representing the simulation steps described in section 5.2.1, an example of use case related to the AGGIR toileting variable is presented. Next, the conditions for the achievement of the aforementioned AGGIR variable are introduced: (i) the inhabitant must use the toilet; (ii) after, the chain of the toilet flush must be pulled; (iii) after using the toilet, the inhabitant should have his hands washed. In order to analyze such a variable, the records

created by the presence sensor located within the bathroom area, alongside with the records issued from the use of both the toilet flush sensor and the washbasin proximity sensor, must be examined.

Additionally, with the aim of identifying the AGGIR dressing variable, the rules for the detection of ADL's composing such a variable is defined: (i) the inhabitant must get close to the wardrobe area; (ii) the inhabitant must spend time changing clothes. To this end, data originated by the wardrobe door sensor, as well as the wardrobe proximity sensor, must be gathered.

Moreover, for the purpose of recognizing the AGGIR transfer variable, the constituent events regarding the aforementioned variable must occur: (i) getting up from bed; (ii) taking a seat; (iii) standing up from a chair; not necessarily in that order. In this matter, capacitive sensors located in both bed and chair/armchair are responsible for the data collection.

In order to illustrate the three AGGIR variables outlined above, Fig. 5.5 provides a description of all activities related to the three considered AGGIR variables as well as sensors related to each one.

AGGIR Variable = Situation		
Toileting	**Dressing**	**Transfers**
Situation = $\sum(+)$ Activities		
Open bathroom door	Open wardrobe door	Lying down
Use of toilet flush	Spend time changing clothes	Sitting down
Wash hands Close bathroom door	Close wardrobe door	Getting up
Activity = $\sum(+)$ Sensor data		
Bathroom door sensor (*On–Off* / `Boolean`)	Wardrobe door sensor (*On–Off* / `Boolean`)	Bed capacitive sensor (*On–Off* / `Boolean`)
Toilet flush sensor (*On–Off* / `Boolean`)	Wardrobe proximity sensor (*On–Off* / `Double`)	Chair capacitive sensor (*On–Off* / `Boolean`)
Washbasin proximity sensor (*On–Off* / `Double`)		

Figure 5.5: Orchestration of activities / AGGIR Variables

Also, conditions regarding the achievement of a certain number of events within a period of time must be accomplished for the evaluation of the AGGIR variables.

In order to detect the toileting AGGIR variable the following conditions must be met: the inhabitant must use the toilet, and wash his hands after eating or using the toilet, for at least three times a day.

Furthermore, to calculate the transfer variable, namely the ability of a person to perform the basic movements of his dayly routine, such as rising from bed, sitting down and standing up from a chair; it is considered that there must be at least three sitting events a day, either taking place in the living room or in the kitchen, and at least rising from the bed one time per day.

In addition, the verification of the dressing variable relies on dressing events such as approching the wardrobe at least twice a day.

With a view to perform the evaluation of the AGGIR variables, all the simulating and processing operations are performed by means of two sets of inputs for the introduced framework, in order to generate two different scenarios. For this matter, the week is separated into seven days, each of which is represented by means of one simulation file within the smart home environment simulator.

To this effect, the first scenario is simulated of an ideal week case scenario, meaning that all the ADL's were performed with no impediment by the inhabitant throughout the entire week, by means of a simulated sensor network within a house environment for monitoring the ADL's carried out by the elderly resident. Results obtained from the simulation are presented in Table 5.4, in which, the number of detected activities per day related to each one of the considered AGGIR variables are shown. The check mark means that the criteria for determining that the person is independent (i.e., minimum number of activities related to each variable) has been reached.

Table 5.4: Results of the first scenario.

		Transfer	Toileting	Dressing
No. of events	**MON**	☑ 7	☑ 8	☑ 3
	TUE	☑ 6	☑ 8	☑ 3
	WED	☑ 7	☑ 11	☑ 2
	THU	☑ 7	☑ 10	☑ 2
	FRI	☑ 8	☑ 8	☑ 3
	SAT	☑ 8	☑ 6	☑ 4
	SUN	☑ 6	☑ 9	☑ 3
	Total	☑ 49	☑ 59	☑ 19

For the purpose of generating a malfunctioning on the developed criteria, some of the ADL's related to the evaluated AGGIR variables were randomly excluded in the second scenario during the seven-day period of analysis. Once the simulation was conducted, the obtained results demonstrate that the detection of complex events regarding either the achievement or the absence of ADL's were carried out succesfully, according to the preestablished conditions, as enlisted on Table 5.5.

Table 5.5: Results of the second scenario.

		Transfer	Toileting	Dressing
No. of events	**MON**	☑ 7	☑ 7	☑ 3
	TUE	☑ 7	☑ 7	☒ 0
	WED	☑ 7	☑ 11	☑ 2
	THU	☑ 6	☑ 11	☑ 3
	FRI	☑ 8	☑ 8	☑ 3
	SAT	☒ 3	☑ 6	☑ 4
	SUN	☑ 6	☒ 6	☑ 2
	Total	☑ 44	☒ 56	☑ 16

Furthermore, the proposed method succeeded in identifying three simulated problems within a week. The days were randomly chosen. Fig. 5.6 and Fig. 5.7 show that despite the number of records in the second scenario related to personal transfer and toileting did not change significantly compared to the first analyzed scenario, however a problem with the dressing variable was detected, as illustrated on Fig. 5.8. This, in turn, reflects the how the DSL event descriptor can perform a smart analysis of events.

The experiment was designed in order to discuss three concepts: the first is calculating the constants of the AGGIR grid: dressing, transfer, and toileting. using the suggested method.

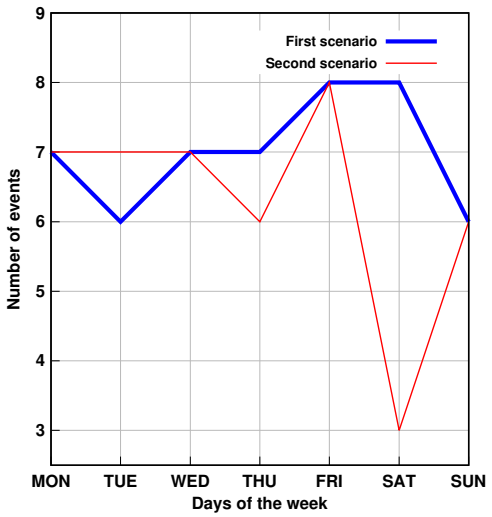


Figure 5.6: AGGIR Transfer events

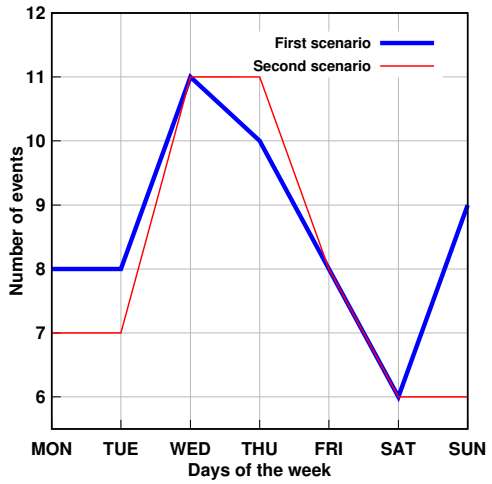


Figure 5.7: AGGIR Toileting events

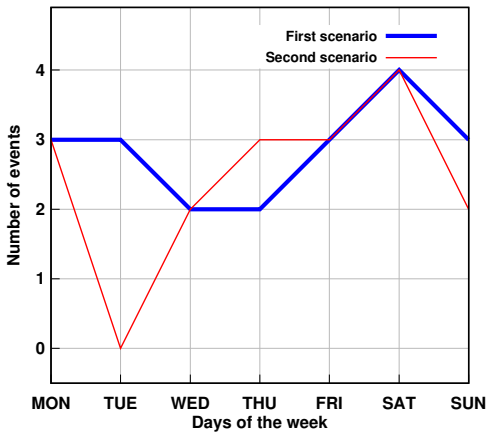


Figure 5.8: AGGIR Dressing events

The second is the framework scalability, where the time frame is expanded to verify the ability of the framework to deal with larger time domains and thousands of records and events. Finally, the algorithm performance is also examined for different simulation times. In what follows, the

results regarding these two latter are presented.

Framework scalability

Subsequently, with the aim of validating the execution of the framework under event processing conditions regarding both larger time domains and higher workload cases; the scalability of the framework for a period of time longer than one week was tested. For this matter, a time lapse of three months was simulated in order to generate the corresponding records. Next, the proposed criteria were applied with the intent to create the events; and thus calculte the values of the three AGGIR variables: toileting, tranfers, dressing. In addition, with a view to allow flexibility when processing records and generating events, the assumption that each month is conformed by thirty days was considered. By doing so, there is a possibility to perform the required simulations by employing an approximate number of days per month; i.e., 28, 29, 30 and 31 days (Fig. 5.9).

Finally, to make sure that the algorithm is scalable, the time elapsed during the calculation of the three abovementioned AGGIR variables for simulation time periods for one day, one week, two weeks, three weeks, a month, two months, and three months; were monitored. Table 5.6 summarizes the elapsed time for each case. The values displayed include the time spent for each simulation, as well as results analysis, events generation, and finally the calculation of the AGGIR variable.

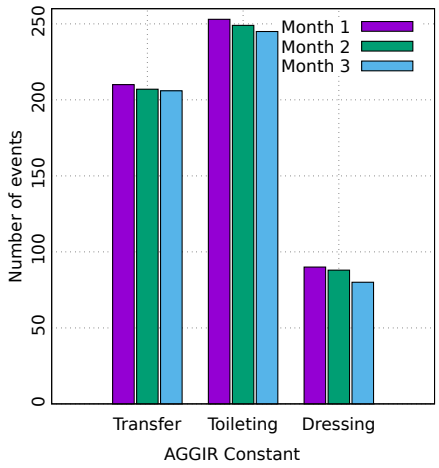


Figure 5.9: Three-month algorithm scalability

Table 5.6: Real time elapsed to calculate the constants in seven different simulation time ranges (***D***ay, ***W***eek, ***M***onth).

Time period	1***D***	1***W***	2***W***	3***W***	1***M***	2***M***	3***M***
No. of days	1	7	14	21	30	60	90
Time (*s*)	62	434	867	1301	1863	3713	5590

In order to present the results thus achieved, Fig. 5.10 shows the performance of the algorithm with simulating scenarios carried out with different time ranges. As a result, the obtained diagram is linear, which corresponds to the complexity of the algorithm of the Analyzer module, represented by $O(n)$, where n defines the number of events, implying that the framework as a whole, is scalable.

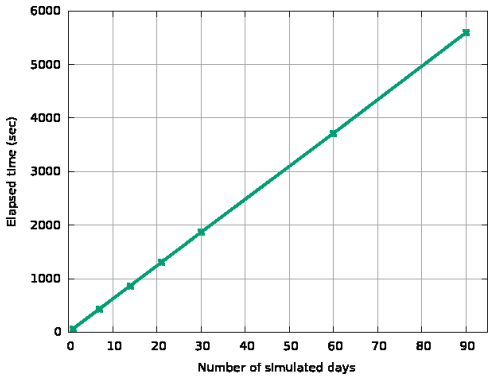


Figure 5.10: Analysis of Algorithm performance

5.3 Conclusions

In this chapter, in order to evaluate the performance of the proposed DSL, experimentation regarding the recognition of the discriminatory AGGIR variables, as well as situations with regard to health care measurements performed by the inhabitant himself by means of medical devices, is presented.

For the purpose of performing the analysis in the introduced framework, the methodology simulation steps are explained, in which the procedure indicating the generation of scenarios ragarding ADL's for a one-week period is defined. In addition, due to the fact that identification of either the performance or absence of the events conforming the AGGIR variables must be detected, two scenarios are considered for each experiment. For this matter, the first scenario consists of a seven-day period during which all the ADL's were carried out to completion, whereas for the second scenario, some activities were left out with a view to provoke an irregular fonctioning in the suggested criteria during the same period of time.

With the aim of applying the abovementioned steps, several use cases are provided; namely, the alimentation, toileting, cooking and transfer AGGIR variables; as well as a description regarding an use case of a medical device for measuring blood glucose level. Moreover, results obtained show that the proposed framework suceeding on detecting the events and therefore the AGGIR variables according to preestablished conditions present in the experimentation scenarios.

In the next chapter, conclusions with regard to this work are introduced, as well as remarks outlining future work directions.

Chapter 6

Conclusions and Future Work

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In this chapter, with the aim of reviewing the contributions achieved concerning the challenges proposed in chapter 1, conclusios with regard to this thesis work are provided. Furthermore, in order to highlight potential future work to follow up, research directions are introduced.

6.1 Conclusions

In the conclusion section, we recapitulate the goals accomplished during this research , as well as the limitations we faced to achieve such goals.

In recent years, it has been reported that the population sector targeted as elderly is increasing more rapidly than in the previous decades. Besides that, age-related health issues as well as different chronic diseases start to become apparent at this stage of life. Moreover, various surveys indicate that elderly people are willing to live independently in their own homes as long as possible.

In order to assess the abovementioned problem, personal sensor networks and body sensor networks in smart environments represent an option regarding healthcare solutions for monitoring elderly people at home.

However, despite their popularity, the abscence of a monitoring approach with regard to a dependency evaluation model such as the AGGIR grid variables has never been treated. For this matter, a DSL with a view to supervise the elderly at home relying on the AGGIR grid tool is presented in this work.

Next, with a view to summarize the achievements of this study, accomplishements are described in the next paragraphs.

6.1.1 Research Achievements

After describing a general overview of the research work proposed in this thesis, the achievements accomplished in this dissertation are presented.

In order to describe the monitoring of ADL's that respond to the fields of support for elderly, diseases connected to aging, people with a physical or mental disability; in this thesis work, a

DSL based on the AGGIR grid dependency model is proposed.

The core contributions of this research work are: (i) a state-of-the-art related to the proposed subject; (ii) a DSL relying on the AGGIR grid evaluation model for assessing the performance of ADL's of the elderly/handicapped at home; (iii) a framework tool for validating the proposed DSL. The aforementioned contributions are described in what follows:

- **A state-of-the-art related to the proposed subject**: With the aim of retrieving information serving as a background for the introduced apprach; analysis of existing solutions and related studies carried out. To this extent, future circumstances with regard to aging population, as well as the capabilities of technology for assisting the maintenance of and monitoring the health needs of people, are reviewed. In addition, dependency evaluation models were presented.

- **A Domain Specic Language (DSL) for assessing the AGGIR grid variables**: For the purpose of dealing with the orchestration for determining ADL's performed by the elderly inhabitant, as well as identifying the AGGIR grid variables; a DSL relying on both temporal and location operators is described.

- **A framework for validating the proposed DSL**: With a view to validate the aforementioned DSL, a framework architecture is presented in order to fulfill the requirements for processing complex events. Moreover, the framework is composed by: (i) the DSL as its main component, (ii) the incorporation of the DSL to a smart-home simulator called iCASA for carrying out evaluation and experimentation; (iii) the generation of a parser in charge of processing the data issued from the DSL aimed to create the appropriate instructions for the iCASA platform.

The main contributions of the present research study have been presented. Subsequently, with the goal of highlighting future work, various approaches that can be considerd are introduced.

6.2 Future Work

After explaining use case applications of the introduced approach, in order to establish the perspectives that can be considered for a future work are presented in this section. Moreover, research directions for this matter are proposed as well.

With the aim of providing a list of work extensions that can be applied to the forthcoming development tasks with regard to the present study, future appplications are given as follows:

1. **Proposing the identification of a three-state variable approach for the AGGIR grid**: Due to fact that the current version of the introduced DSL is only able to recognise two of the three values (**A** for complete dependency, and **C** for complete independency) of the AGGIR grid variables; the proposal of an improved version of the DSL comprehending the three states of identification (including **B** for partial dependency), is one of the possible directions of the future work.

2. **Evaluating in detail critical activities defining intangible variables**: For the purpose of assessing AGGIR variables that can be considered as more elaborate, such as coherence, further experimentation is required to evaluate crucial activities describing the concerned variable.

3. **Integrating the assesment of the AGGIR illustrative variables**: Even though the presented approach considers the evaluation of the AGGIR discriminatory variables; with the goal of covering the whole spectrum of the AGGIR variables, the integration of the AGGIR illustrative variables is one of the next steps to be taken.

4. **Developing and integrating different dependency evaluation models**: So far, the perspective introduced in this research relies on the AGGIR grid variables. In order to expand the coverage of the suggested approach, the inclusion of other dependency evaluation models; e.g. the Functional Autonomy Measurement System (SMAF) model, represents a field of opportunity to broaden the scope of the present work.

5. **Testing the adaptability with people external to the household**: Besides the presence of the house residents, visitors can represent a factor for change regarding the household dynamics. For this matter, the adaptability of the proposed approach must be determined by tests concerning unknown users to the smart-home environment; as well as the impact that their visit may cause to the actual inhabitants.

6. **Application use within a realistic smart-home environment**: Despite the fact of having employed a smart-home simulator, as well as a schedule describing the actual activities that were carried out by the user; the application of the present work for real-time use cases is recommended. To this extent, monitoring of ADL's within an actual smart-home environment would be ideal for testing the present approach in a real-time scenario.

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Bibliography

[1] Aamodt, A. and Plaza, E. (1994). Case-based reasoning: Foundational issues, methodological variations, and system approaches. *AI communications*, 7(1):39–59. 17

[2] Abowd, G. D., Dey, A. K., Brown, P. J., Davies, N., Smith, M., and Steggles, P. (1999). Towards a better understanding of context and context-awareness. In *International symposium on handheld and ubiquitous computing*, pages 304–307. Springer. 3

[3] Acampora, G., Cook, D. J., Rashidi, P., and Vasilakos, A. V. (2013). A survey on ambient intelligence in healthcare. *Proceedings of the IEEE*, 101(12):2470–2494. 2

[4] Adami, A. M., Pavel, M., Hayes, T. L., and Singer, C. M. (2010). Detection of movement in bed using unobtrusive load cell sensors. *IEEE Transactions on Information Technology in Biomedicine*, 14(2):481–490. 15

[5] Alcañiz, M. and Rey, B. (2005). New technologies for ambient intelligence. *Ambient Intelligence*, 3:3–15. 9

[6] Allen, J. F. (1990). Maintaining knowledge about temporal intervals. In *Readings in qualitative reasoning about physical systems*, pages 361–372. Elsevier. 33, 35, 47, 77

[7] Alliance, O. (2009). Osgi alliance: Osgi service platform, core specification, release 4, version 4.2. *OSGi Alliance*. 52

[8] Altun, K., Barshan, B., and Tunçel, O. (2010). Comparative study on classifying human activities with miniature inertial and magnetic sensors. *Pattern Recognition*, 43(10):3605–3620. 11

[9] Alwan, M. and Nobel, J. (2008). State of technology in aging services according to field experts and thought leaders. *CAST (LeadingAge Center for Aging Services Technology), Washington, DC, March*. 2

[10] Amrani, M., Gilson, F., and Englebert, V. (2017). Complex event processing for user-centric management of iot systems. In *International Conference on Model-Driven Engineering and Software Development*, pages 426–448. Springer. 27, 28, 75

[11] Angsuchotmetee, C., Chbeir, R., Cardinale, Y., and Yokoyama, S. (2017). A dynamic event detection framework for multimedia sensor networks. In *Asia-Pacific Conference on Communications*, pages 1–6. IEEE. 34, 35, 39, 77

[12] Augusto, J. C., Liu, J., McCullagh, P., Wang, H., and Yang, J.-B. (2008). Management of uncertainty and spatio-temporal aspects for monitoring and diagnosis in a smart home. *International Journal of Computational Intelligence Systems*, 1(4):361–378. 33

[13] Aztiria, A., Izaguirre, A., and Augusto, J. C. (2010). Learning patterns in ambient intelligence environments: a survey. *Artificial Intelligence Review*, 34(1):35–51. 16

[14] Badlani, A. and Bhanot, S. (2011). Smart home system design based on artificial neural networks. In *Proceedings of the World Congress on Engineering and Computer Science*, volume 1, pages 146–164. 16

[15] Banos, O., Villalonga, C., Damas, M., Gloesekoetter, P., Pomares, H., and Rojas, I. (2014). Physiodroid: Combining wearable health sensors and mobile devices for a ubiquitous, continuous, and personal monitoring. *The Scientific World Journal*, 2014. 40

[16] Barth, A. T., Hanson, M. A., Powell Jr, H. C., and Lach, J. (2009). Tempo 3.1: A body area sensor network platform for continuous movement assessment. In *2009 Body Sensor Networks*, pages 71–76. IEEE. 15

[17] Berchtold, M., Budde, M., Gordon, D., Schmidtke, H. R., and Beigl, M. (2010). Actiserv: Activity recognition service for mobile phones. In *International Symposium on Wearable Computers (ISWC) 2010*, pages 1–8. IEEE. 11

[18] Bettini, C., Brdiczka, O., Henricksen, K., Indulska, J., Nicklas, D., Ranganathan, A., and Riboni, D. (2010). A survey of context modelling and reasoning techniques. *Pervasive and Mobile Computing*, 6(2):161–180. 16

[19] Biacino, L. and Gerla, G. (2002). Fuzzy logic, continuity and effectiveness. *Archive for Mathematical Logic*, 41(7):643–667. 17

[20] Bienkowska-Gibbs, T., King, S., Saunders, C., and Henham, M.-L. (2015). New organisational models of primary care to meet the future needs of the nhs. *A brief overview of recent reports. RAND Europe*. 8

[21] Black, A. D., Car, J., Pagliari, C., Anandan, C., Cresswell, K., Bokun, T., McKinstry, B., Procter, R., Majeed, A., and Sheikh, A. (2011). The impact of ehealth on the quality and safety of health care: a systematic overview. *PLoS medicine*, 8(1):e1000387. 10

[22] Boubeta-Puig, J., Ortiz, G., and Medina-Bulo, I. (2015). Model4cep: Graphical domain-specific modeling languages for cep domains and event patterns. *Expert Systems with Applications*, 42(21):8095–8110. 28

[23] Brdiczka, O., Reignier, P., and Crowley, J. L. (2005). Supervised learning of an abstract context model for an intelligent environment. In *Proceedings of the 2005 joint conference on Smart objects and ambient intelligence: innovative context-aware services: usages and technologies*, pages 259–264. ACM. 16

[24] Bruno, B., Grosinger, J., Mastrogiovanni, F., Pecora, F., Saffiotti, A., Sathyakeerthy, S., and Sgorbissa, A. (2015). Multi-modal sensing for human activity recognition. In *Int. Symp. on Robot and Human Interactive Communication*, pages 594–600. IEEE. 35, 38, 39

[25] Burns, A., Greene, B. R., McGrath, M. J., O'Shea, T. J., Kuris, B., Ayer, S. M., Stroiescu, F., and Cionca, V. (2010). Shimmer™–a wireless sensor platform for noninvasive biomedical research. *IEEE Sensors Journal*, 10(9):1527–1534. 40

[26] Caione, A., Fiore, A., Mainetti, L., Manco, L., and Vergallo, R. (2018). Top-down delivery of iot-based applications for seniors behavior change capturing exploiting a model-driven approach. *Journal of Communications Software and Systems*, 14. 30, 31, 32, 75, 77

[27] Chan, M., Hariton, C., Ringeard, P., and Campo, E. (1995). Smart house automation system for the elderly and the disabled. In *1995 IEEE International Conference on Systems, Man and Cybernetics. Intelligent Systems for the 21st Century*, volume 2, pages 1586–1589. IEEE. 16

[28] Chattopadhyay, S., Banerjee, S., Rabhi, F. A., and Acharya, U. R. (2013). A case-based reasoning system for complex medical diagnosis. *Expert Systems*, 30(1):12–20. 17

[29] Chen, C., Zhang, D., Sun, L., Hariz, M., and Yuan, Y. (2012). Does location help daily activity recognition? In *International Conference on Smart Homes and Health Telematics*, pages 83–90. Springer. 12, 13

[30] Chernbumroong, S., Cang, S., Atkins, A., and Yu, H. (2013). Elderly activities recognition and classification for applications in assisted living. *Expert Systems with Applications*, 40(5):1662–1674. 3, 12, 14

[31] Chien, T.-W., Wu, H.-M., Wang, W.-C., Castillo, R. V., and Chou, W. (2009). Reduction in patient burdens with graphical computerized adaptive testing on the adl scale: tool development and simulation. *Health and Quality of Life Outcomes*, 7(1):39. 2

[32] Consel, C. (2004). From a program family to a domain-specific language. In *Domain-Specific Program Generation*, pages 19–29. Springer. 37

[33] Cook, D. J., Augusto, J. C., and Jakkula, V. R. (2009). Ambient intelligence: Technologies, applications, and opportunities. *Pervasive and Mobile Computing*, 5(4):277–298. 2, 33

[34] Cook, D. J., Huber, M., Gopalratnam, K., and Youngblood, M. (2003a). Learning to control a smart home environment. In *Innovative applications of artificial intelligence*. 15

[35] Cook, D. J., Youngblood, M., Heierman, E. O., Gopalratnam, K., Rao, S., Litvin, A., and Khawaja, F. (2003b). Mavhome: An agent-based smart home. In *Proceedings of the First IEEE International Conference on Pervasive Computing and Communications, 2003.(PerCom 2003).*, pages 521–524. IEEE. 15

[36] de Kruijff, J. and Weigand, H. (2018). An introduction to commitment based smart contracts using reactionruleml. In *VMBO*, pages 149–157. 27, 75

[37] de la Torre-García, M., Hernández-Santana, A., Moreno-Moreu, N., Luis-Jacinto, R., Deive-Maggiolo, J., and Rodriguez, J. (2011). Use of the barthel index to measure functional recovery in an elderly population after hip fracture. *Revista Española de Cirugía Ortopédica y Traumatología (English Edition)*, 55(4):263–269. 18

[38] Dernbach, S., Das, B., Krishnan, N. C., Thomas, B. L., and Cook, D. J. (2012). Simple and complex activity recognition through smart phones. In *2012 Eighth International Conference on Intelligent Environments*, pages 214–221. IEEE. 15

[39] Dishongh, T. J. and McGrath, M. (2010). *Wireless sensor networks for healthcare applications*. Artech House. 10

[40] Dormont, B., Martin, C., et al. (2011). L'efficacité des ehpad en france. Technical report, Université Paris-Dauphine. 20, 21

[41] Dubuc, N., Hébert, R., Desrosiers, J., Buteau, M., and Trottier, L. (2006). Disability-based classification system for older people in integrated long-term care services: the iso-smaf profiles. *Archives of gerontology and geriatrics*, 42(2):191–206. 20

[42] Ducatel, K., Bogdanowicz, M., Scapolo, F., LEIJTEN, J., and BURGELMAN, J. (2001). Istag scenarios for ambient intelligence in 2010. final report. *European Commission, Feb.* 15

[43] Dupourqué, E., Schoonveld, S., and Bushey, J. B. (2012). Aggir, the work of grids. *Long-term Care News*, 32:1–11. 2, 3, 4, 14, 21, 22, 23, 77

[44] Efftinge, S., Eysholdt, M., Köhnlein, J., Zarnekow, S., von Massow, R., Hasselbring, W., and Hanus, M. (2012). Xbase: implementing domain-specific languages for java. In *ACM SIGPLAN Notices*, volume 48, pages 112–121. ACM. 26

[45] Ermes, M., Parkka, J., and Cluitmans, L. (2008). Advancing from offline to online activity recognition with wearable sensors. In *2008 30th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, pages 4451–4454. IEEE. 10

[46] Escoffier, C., Hall, R. S., and Lalanda, P. (2007). ipojo: An extensible service-oriented component framework. In *Int. Conf. on Services Computing*, pages 474–481. IEEE. 52

[47] Farber, N., Shinkle, D., Lynott, J., Fox-Grage, W., and Harrell, R. (2011). Aging in place: A state survey of livability policies and practices. 1

[48] Fowler, M. (2010). *Domain-specific languages*. Pearson Education. 26

[49] Franco, C., Demongeot, J., Villemazet, C., and Vuillerme, N. (2010). Behavioral telemonitoring of the elderly at home: Detection of nycthemeral rhythms drifts from location data. In *2010 IEEE 24th International Conference on Advanced Information Networking and Applications Workshops*, pages 759–766. IEEE. 15

[50] Freksa, C. (1992). Temporal reasoning based on semi-intervals. *Artificial intelligence*, 54(1-2):199–227. 34, 35, 39, 77

[51] Furze, T. A. and Bennett, B. (2011). Using the principles of classical conditioning to learn event sequences. *Computational Models Of Cognitive Development*, pages 40–47. 35, 36, 39, 77

[52] Galton, A. (1994). Lines of sight. In *AISB Workshop on Spatial and Spatio-Temporal Reasoning*. 35, 37, 39, 75

[53] Galushka, M., Patterson, D., and Rooney, N. (2006). Temporal data mining for smart homes. In *Designing Smart Homes*, pages 85–108. Springer. 16

[54] Goguen, J. A. (1969). The logic of inexact concepts. *Synthese*, 19(3):325–373. 17

[55] Gordon, D., Czerny, J., Miyaki, T., and Beigl, M. (2012). Energy-efficient activity recognition using prediction. In *2012 16th International Symposium on Wearable Computers*, pages 29–36. IEEE. 11

[56] Gottfried, B., Guesgen, H. W., and Hübner, S. (2006). Spatiotemporal reasoning for smart homes. In *Designing Smart Homes*, pages 16–34. Springer. 33

[57] Goulão, M., Amaral, V., and Mernik, M. (2016). Quality in model-driven engineering: a tertiary study. *Software Quality Journal*, 24(3):601–633. 26

[58] Graf, C. (2008). The lawton instrumental activities of daily living scale. *AJN The American Journal of Nursing*, 108(4):52–62. 18

[59] Guo, M., Zhou, J., Tang, F., and Shen, Y. (2016). *Pervasive computing: concepts, technologies and applications*. CRC Press. 2

[60] Haidrar, S., Anwar, A., Bruel, J.-M., and Roudies, O. (2018). A domain-specific language to manage requirements traceability. *JSW*, 13(9):460–480. 27, 29, 75

[61] Hébert, R., Carrier, R., and Bilodeau, A. (1988). The functional autonomy measurement system (smaf): description and validation of an instrument for the measurement of handicaps. *Age and ageing*, 17(5):293–302. 20

[62] Heierman, E. O. and Cook, D. J. (2003). Improving home automation by discovering regularly occurring device usage patterns. In *Third IEEE International conference on data mining*, pages 537–540. IEEE. 15

[63] Helal, S., Winkler, B., Lee, C., Kaddoura, Y., Ran, L., Giraldo, C., Kuchibhotla, S., and Mann, W. (2003). Enabling location-aware pervasive computing applications for the elderly. In *Proceedings of the First IEEE International Conference on Pervasive Computing and Communications, 2003.(PerCom 2003).*, pages 531–536. IEEE. 15

[64] Helaoui, R., Niepert, M., and Stuckenschmidt, H. (2011). Recognizing interleaved and concurrent activities: A statistical-relational approach. In *2011 IEEE International Conference on Pervasive Computing and Communications (PerCom)*, pages 1–9. IEEE. 45

[65] Hemapriya, D., Viswanath, P., Mithra, V., Nagalakshmi, S., and Umarani, G. (2017). Wearable medical devices—design challenges and issues. In *2017 International Conference on Innovations in Green Energy and Healthcare Technologies (IGEHT)*, pages 1–6. IEEE. 10

[66] Henderson, P. (1982). Functional geometry. In *Proceedings of the 1982 ACM symposium on LISP and functional programming*, pages 179–187. ACM. 26

[67] Henricksen, K., Indulska, J., and Rakotonirainy, A. (2002). Modeling context information in pervasive computing systems. In *International Conference on Pervasive Computing*, pages 167–180. Springer. 4

[68] Hetherington, H., Earlam, R., and Kirk, C. (1995). The disability status of injured patients measured by the functional independence measure (fim) and their use of rehabilitation services. *Injury*, 26(2):97–101. 19

[69] Hoelzl, G., Kurz, M., and Ferscha, A. (2012). Goal oriented opportunistic recognition of high-level composed activities using dynamically configured hidden markov models. *Procedia Computer Science*, 10:308–315. 11

[70] Hong, J., Suh, E.-H., Kim, J., and Kim, S. (2009). Context-aware system for proactive personalized service based on context history. *Expert Systems with Applications*, 36(4):7448–7457. 4

[71] Hori, T. and Nishida, Y. (2005). Ultrasonic sensors for the elderly and caregivers in a nursing home. In *ICEIS*, pages 110–115. Citeseer. 15

[72] Hsu, C.-C. and Chen, J.-H. (2011). A novel sensor-assisted rfid-based indoor tracking system for the elderly living alone. *Sensors*, 11(11):10094–10113. 15

[73] Huynh, T., Fritz, M., and Schiele, B. (2008). Discovery of activity patterns using topic models. In *UbiComp*, volume 8, pages 10–19. 11

[74] Hunh, T., Blanke, U., and Schiele, B. (2007). Scalable recognition of daily activities with wearable sensors. In *International Symposium on Location-and Context-Awareness*, pages 50–67. Springer. 11

[75] Jih, W.-r., Hsu, J. Y.-j., Wu, C.-L., Liao, C.-F., and Cheng, S.-y. (2006). A multi-agent service framework for context-aware elder care. In *In AAMAS*. 3, 12, 14, 15

[76] Joël, M.-E., Dufour-Kippelen, S., Duchêne, C., and Marmier, M. (2010). *The long-term care system for the elderly in France*. Centre for European Policy Studies. 22, 77

[77] Kakria, P., Tripathi, N., and Kitipawang, P. (2015). A real-time health monitoring system for remote cardiac patients using smartphone and wearable sensors. *International journal of telemedicine and applications*, 2015:8. 40

[78] Kamel Boulos, M. N., Lou, R. C., Anastasiou, A., Nugent, C. D., Alexandersson, J., Zimmermann, G., Cortes, U., and Casas, R. (2009). Connectivity for healthcare and well-being management: examples from six european projects. *Int. J. of environmental research and public health*, 6(7):1947–1971. 1, 8

[79] Kang, D.-o., Kang, K., Lee, H.-j., Ko, E.-j., and Lee, J. (2007). A systematic design tool of context aware system for ubiquitous healthcare service in a smart home. In *Future generation communication and networking (fgcn 2007)*, volume 2, pages 49–54. IEEE. 15

[80] Kang, D.-O., Lee, H.-J., Ko, E.-J., Kang, K., and Lee, J. (2006). A wearable context aware system for ubiquitous healthcare. In *2006 International Conference of the IEEE Engineering in Medicine and Biology Society*, pages 5192–5195. IEEE. 15

[81] Karsai, G., Krahn, H., Pinkernell, C., Rumpe, B., Schindler, M., and Völkel, S. (2014). Design guidelines for domain specific languages. *arXiv preprint arXiv:1409.2378*. 26, 77

[82] Katz, S. (1963). Studies of illness in the aged. the index of adl: a standardized measure of biologic and psychologic function. *JaMa*, 185:94–99. 2, 12, 18

[83] Katz, S., Downs, T. D., Cash, H. R., and Grotz, R. C. (1970). Progress in development of the index of adl. *The gerontologist*, 10(1_Part_1):20–30. 18

[84] Kautz, H., Arnstein, L., Borriello, G., Etzioni, O., and Fox, D. (2002). An overview of the assisted cognition project. In *AAAI-2002 Workshop on Automation as Caregiver: The Role of Intelligent Technology in Elder Care*, number 2002, page 6065. 15

[85] Keith, R. A. (1987). The functional independence measure: a new tool for rehabilitation. *Advances in clinical rehabilitation*, 2:6–18. 18

[86] Khan, A. M., Lee, Y.-K., Lee, S.-Y., and Kim, T.-S. (2010). Human activity recognition via an accelerometer-enabled-smartphone using kernel discriminant analysis. In *2010 5th international conference on future information technology*, pages 1–6. IEEE. 15

[87] Kim, E., Helal, S., and Cook, D. (2010a). Human activity recognition and pattern discovery. *IEEE Pervasive Computing/IEEE Computer Society [and] IEEE Communications Society*, 9(1):48. 12

[88] Kim, J., Choi, H.-s., Wang, H., Agoulmine, N., Deerv, M. J., and Hong, J. W.-K. (2010b). Postech's u-health smart home for elderly monitoring and support. In *Int. Symp on World of Wireless Mobile and Multimedia Networks*, pages 1–6. IEEE. 35, 38, 39

[89] Kosar, T., Bohra, S., and Mernik, M. (2016). Domain-specific languages: A systematic mapping study. *Information and Software Technology*, 71:77–91. 26, 27

[90] Kramer, D., Augusto, J. C., and Clark, T. (2014). Context-awareness to increase inclusion of people with ds in society. In *Workshops at the Twenty-Eighth AAAI Conference on Artificial Intelligence*. 4

[91] Kringos, D. S., Boerma, W. G., Hutchinson, A., and Saltman, R. B. (2015). *Building primary care in a changing Europe*. WHO Regional Office for Europe. 8

[92] Krishnan, N. C., Colbry, D., Juillard, C., and Panchanathan, S. (2008). Real time human activity recognition using tri-axial accelerometers. In *Sensors, signals and information processing workshop*, pages 3337–3340. 15

[93] Kushwaha, N., Kim, M., Kim, D. Y., and Cho, W.-D. (2004). An intelligent agent for ubiquitous computing environments: smart home ut-agent. In *Second IEEE Workshop on Software Technologies for Future Embedded and Ubiquitous Systems, 2004. Proceedings.*, pages 157–159. IEEE. 17

[94] Kwapisz, J. R., Weiss, G. M., and Moore, S. A. (2011). Activity recognition using cell phone accelerometers. *ACM SigKDD Explorations Newsletter*, 12(2):74–82. 11, 15

[95] Lalanda, P., Hamon, C., Escoffier, C., and Leveque, T. (2014). icasa, a development and simulation environment for pervasive home applications. In *Consumer Communications and Networking Conference*, pages 1142–1143. IEEE. 52

[96] Lalanda, P., McCann, J. A., and Diaconescu, A. (2013). *Autonomic computing*. Springer. 52

[97] Lane, N. D., Miluzzo, E., Lu, H., Peebles, D., Choudhury, T., and Campbell, A. T. (2010). A survey of mobile phone sensing. *IEEE Communications magazine*, 48(9):140–150. 16

[98] Lawton, M. P. and Brody, E. M. (1969). Assessment of older people: self-maintaining and instrumental activities of daily living. *The gerontologist*, 9(3_Part_1):179–186. 2, 12, 18

[99] Leake, D., Maguitman, A., and Reichherzer, T. (2006). Cases, context, and comfort: Opportunities for case-based reasoning in smart homes. In *Designing Smart Homes*, pages 109–131. Springer. 16

[100] Lee, M.-h., Kim, J., Kim, K., Lee, I., Jee, S. H., and Yoo, S. K. (2009). Physical activity recognition using a single tri-axis accelerometer. In *Proceedings of the world congress on engineering and computer science*, volume 1. 10

[101] Lee, M.-W., Khan, A. M., and Kim, T.-S. (2011). A single tri-axial accelerometer-based real-time personal life log system capable of human activity recognition and exercise information generation. *Personal and Ubiquitous Computing*, 15(8):887–898. 10

[102] Lee, Y.-D. and Chung, W.-Y. (2009). Wireless sensor network based wearable smart shirt for ubiquitous health and activity monitoring. *Sensors and Actuators B: Chemical*, 140(2):390–395. 15

[103] Lemlouma, T., Laborie, S., and Roose, P. (2013). Toward a context-aware and automatic evaluation of elderly dependency in smart homes and cities. In *Int. Symp. on World of Wireless, Mobile and Multimedia Networks*, pages 1–6. IEEE. 3, 12, 14

[104] Li, X.-S., Tao, X.-P., Song, W., and Dong, K. (2018). Aocml: A domain-specific language for model-driven development of activity-oriented context-aware applications. *Journal of Computer Science and Technology*, 33(5):900–917. 29, 30, 32, 75

[105] Liao, L., Fox, D., and Kautz, H. (2007). Extracting places and activities from gps traces using hierarchical conditional random fields. *The International Journal of Robotics Research*, 26(1):119–134. 33

[106] Liao, L., Patterson, D. J., Fox, D., and Kautz, H. (2004). Behavior recognition in assisted cognition. In *Proceedings The AAAI-04 Workshop on Supervisory Control of Learning and Adaptive Systems*. 15

[107] Lima, K., Marques, E. R., Pinto, J., and Sousa, J. B. (2018). Dolphin: a task orchestration language for autonomous vehicle networks. In *2018 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, pages 603–610. IEEE. 28, 29, 75

[108] Liu, Y., Zhu, S. H., Wang, G. H., Ye, F., and Li, P. Z. (2013). Validity and reliability of multiparameter physiological measurements recorded by the equivital lifemonitor during activities of various intensities. *Journal of occupational and environmental hygiene*, 10(2):78–85. 40

[109] Long, X., Yin, B., and Aarts, R. M. (2009). Single-accelerometer-based daily physical activity classification. In *2009 Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, pages 6107–6110. IEEE. 10

[110] Lu, C.-H. and Fu, L.-C. (2009). Robust location-aware activity recognition using wireless sensor network in an attentive home. *IEEE Trans. on Automation Science and Engineering*, 6(4):598–609. 3, 12, 14

[111] Lukowicz, P., Pirkl, G., Bannach, D., Wagner, F., Calatroni, A., Förster, K., Holleczek, T., Rossi, M., Roggen, D., Tröster, G., et al. (2010). Recording a complex, multi modal activity data set for context recognition. In *23th International Conference on Architecture of Computing Systems 2010*, pages 1–6. VDE. 12

[112] Lum, W. Y. and Lau, F. C. (2002). A context-aware decision engine for content adaptation. *IEEE Pervasive computing*, 1(3):41–49. 16

[113] Lyytinen, K. and Yoo, Y. (2002). Ubiquitous computing. *Communications of the ACM*, 45(12):63–96. 9

[114] Maekawa, T., Kishino, Y., Yanagisawa, Y., and Sakurai, Y. (2012). Mimic sensors: battery-shaped sensor node for detecting electrical events of handheld devices. In *International Conference on Pervasive Computing*, pages 20–38. Springer. 12, 13

[115] Maekawa, T., Yanagisawa, Y., Kishino, Y., Ishiguro, K., Kamei, K., Sakurai, Y., and Okadome, T. (2010). Object-based activity recognition with heterogeneous sensors on wrist. In *International Conference on Pervasive Computing*, pages 246–264. Springer. 12

[116] Mahoney, F. I. and Barthel, D. W. (1965). Functional evaluation: the barthel index: a simple index of independence useful in scoring improvement in the rehabilitation of the chronically ill. *Maryland state medical journal*. 18

[117] Mainetti, L., Manco, L., Patrono, L., Secco, A., Sergi, I., and Vergallo, R. (2016). An ambient assisted living system for elderly assistance applications. In *2016 IEEE 27th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC)*, pages 1–6. IEEE. 30, 32, 77

[118] Makris, P., Skoutas, D. N., and Skianis, C. (2013). A survey on context-aware mobile and wireless networking: On networking and computing environments' integration. *IEEE communications surveys & tutorials*, 15(1):362–386. 15

[119] Mattila, E., Korhonen, I., and Saranummi, N. (2007). Mobile and personal health and wellness management systems. *Pervasive computing in healthcare*, pages 105–134. 9

[120] Maurer, U., Smailagic, A., Siewiorek, D. P., and Deisher, M. (2006). Activity recognition and monitoring using multiple sensors on different body positions. In *Proceedings of the International Workshop on Wearable and Implantable Body Sensor Networks*, pages 113–116. IEEE Computer Society. 15

[121] McCullagh, P. J. and Augusto, J. C. (2011). The internet of things: The potential to facilitate health and wellness. *CEPIS Upgrade*, 12(1):59–68. 10

[122] McFadden, T. and Indulska, J. (2004). Context-aware environments for independent living. In *Proceedings of the 3rd National Conference of Emerging Researchers in Ageing*, volume 1, page 6. 2

[123] Mernik, M., Heering, J., and Sloane, A. M. (2005). When and how to develop domain-specific languages. *ACM computing surveys (CSUR)*, 37(4):316–344. 26, 37

[124] Mitchell, M., Sposaro, F., Wang, A.-I. A., and Tyson, G. (2011). Beat: Bio-environmental android tracking. In *2011 IEEE Radio and Wireless Symposium*, pages 402–405. IEEE. 40

[125] Mozer, M. C., Dodier, R. H., Anderson, M., Vidmar, L., Cruickshank, R., and Miller, D. (1995). The neural network house: An overview. *Current trends in connectionism*, pages 371–380. 15

[126] Mulero, R., Almeida, A., Azkune, G., Abril-Jiménez, P., Waldmeyer, M. T. A., Castrillo, M. P., Patrono, L., Rametta, P., and Sergi, I. (2018). An iot-aware approach for elderly-friendly cities. *IEEE Access*, 6:7941–7957. 29, 32

[127] Najafi, B., Khan, T., and Wrobel, J. (2011). Laboratory in a box: wearable sensors and its advantages for gait analysis. In *2011 Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, pages 6507–6510. IEEE. 40

[128] Nawaz, F., Janjua, N. K., and Hussain, O. K. (2019). Perceptus: Predictive complex event processing and reasoning for iot-enabled supply chain. *Knowledge-Based Systems*. 27, 28, 77

[129] Noury, N. and Hadidi, T. (2012). Computer simulation of the activity of the elderly person living independently in a health smart home. *Computer methods and programs in biomedicine*, 108(3):1216–1228. 15

[130] OCDE (2017). *Health at a Glance 2017*. 9, 10, 75

[131] Olden, J. D. and Jackson, D. A. (2002). Illuminating the "black box": a randomization approach for understanding variable contributions in artificial neural networks. *Ecological modelling*, 154(1-2):135–150. 16

[132] Orwat, C., Graefe, A., and Faulwasser, T. (2008). Towards pervasive computing in health care–a literature review. *BMC medical informatics and decision making*, 8(1):26. 9

[133] Padovitz, A., Loke, S. W., and Zaslavsky, A. (2008). The ecora framework: A hybrid architecture for context-oriented pervasive computing. *Pervasive and mobile computing*, 4(2):182–215. 17

[134] Parkka, J., Ermes, M., Korpipaa, P., Mantyjarvi, J., Peltola, J., and Korhonen, I. (2006). Activity classification using realistic data from wearable sensors. *IEEE Transactions on information technology in biomedicine*, 10(1):119–128. 10, 11

[135] Patel, S., Mancinelli, C., Healey, J., Moy, M., and Bonato, P. (2009). Using wearable sensors to monitor physical activities of patients with copd: A comparison of classifier performance. In *2009 Sixth International Workshop on Wearable and Implantable Body Sensor Networks*, pages 234–239. IEEE. 11

[136] Patkos, T., Plexousakis, D., Chibani, A., and Amirat, Y. (2016). An event calculus production rule system for reasoning in dynamic and uncertain domains. *Theory and Practice of Logic Programming*, 16(3):325–352. 35, 38, 39

[137] Pavelka, J. (1979). On fuzzy logic i, ii, iii. *Zeit. Math. Logik u. Grundl. Math.*, 25:447–464. 17

[138] Pecht, M. G. (2010). A prognostics and health management roadmap for information and electronics-rich systems. *IEICE ESS Fundamentals Review*, 3(4):4_25–4_32. 15

[139] Pecora, F., Cirillo, M., Dell'Osa, F., Ullberg, J., and Saffiotti, A. (2012). A constraint-based approach for proactive, context-aware human support. *J. of Ambient Intelligence and Smart Environments*, 4(4):347–367. 35, 38, 39

[140] Pfeiffer, M. and Pichler, J. (2008). A comparison of tool support for textual domain-specific languages. In *Proceedings of the 8th OOPSLA Workshop on Domain-Specific Modeling*, pages 1–7. 27

[141] Raîche, M., Hébert, R., Dubois, M.-F., Dubuc, N., et al. (2012). Yearly transitions of disability profiles in older people living at home. *Archives of Gerontology and Geriatrics*, 55(2):399–405. 20, 21, 75

[142] Randell, D., Witkowski, M., and Shanahan, M. (2001). From images to bodies: Modelling and exploiting spatial occlusion and motion parallax. In *IJCAI*, pages 57–66. 35, 37, 39, 75

[143] Randell, D. A., Cui, Z., and Cohn, A. G. (1992). A spatial logic based on regions and connection. 35, 36, 37, 39, 75, 77

[144] Ranganathan, A. and Campbell, R. H. (2003). An infrastructure for context-awareness based on first order logic. *Personal and Ubiquitous Computing*, 7(6):353–364. 16

[145] Rantz, M. J., Skubic, M., Koopman, R. J., Phillips, L., Alexander, G. L., Miller, S. J., and Guevara, R. D. (2011). Using sensor networks to detect urinary tract infections in older adults. In *2011 IEEE 13th International Conference on e-Health Networking, Applications and Services*, pages 142–149. IEEE. 15

[146] Rashidi, P. and Mihailidis, A. (2013). A survey on ambient-assisted living tools for older adults. *IEEE journal of biomedical and health informatics*, 17(3):579–590. 2, 16

[147] Ravi, N., Dandekar, N., Mysore, P., and Littman, M. L. (2005). Activity recognition from accelerometer data. In *Proceedings of the 17th Conference on Innovative Applications of Artificial Intelligence - Volume 3*, IAAI'05, pages 1541–1546. AAAI Press. 15

[148] Reiss, A., Hendeby, G., and Stricker, D. (2013). A competitive approach for human activity recognition on smartphones. In *European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning (ESANN 2013), 24-26 April, Bruges, Belgium*, pages 455–460. ESANN. 12, 13

[149] Ribarić, S. and Dalbelo Bašić, B. (2001). Modelling crisp and fuzzy qualitative temporal relations. *Journal of Information and Organizational Sciences*, 25(2):81–91. 34, 35, 39, 77

[150] Riboni, D. and Bettini, C. (2009). Context-aware activity recognition through a combination of ontological and statistical reasoning. In *International Conference on Ubiquitous Intelligence and Computing*, pages 39–53. Springer. 16

[151] Rivera-Illingworth, F., Callaghan, V., and Hagras, H. (2005). A neural network agent based approach to activity detection in ami environments. In *IEEE international workshop on intelligent environments*, pages 92–99. 15

[152] Rodrigues, R., Huber, M., Lamura, G., et al. (2012). Facts and figures on healthy ageing and long-term care. *European Centre for Social Welfare Policy and Research, Vienna*. 8

[153] Roggen, D., Calatroni, A., Rossi, M., Holleczek, T., Förster, K., Tröster, G., Lukowicz, P., Bannach, D., Pirkl, G., Ferscha, A., et al. (2010). Collecting complex activity datasets in highly rich networked sensor environments. In *2010 Seventh international conference on networked sensing systems (INSS)*, pages 233–240. IEEE. 12

[154] Roldan, E., Neágny, S., Le Lann, J. M., and Cortes, G. (2010). Constraint satisfaction problem for case-based reasoning adaptation: application in process design. In *Computer Aided Chemical Engineering*, volume 28, pages 397–402. Elsevier. 17

[155] Roy, A., Bhaumik, S. D., Bhattacharya, A., Basu, K., Cook, D. J., and Das, S. K. (2003). Location aware resource management in smart homes. In *Proceedings of the First IEEE International Conference on Pervasive Computing and Communications, 2003.(PerCom 2003).*, pages 481–488. IEEE. 15

[156] Rutishauser, U., Joller, J., and Douglas, R. (2005). Control and learning of ambience by an intelligent building. *IEEE Transactions on Systems, Man, and Cybernetics-Part A: Systems and Humans*, 35(1):121–132. 16

[157] Saha, D. and Mukherjee, A. (2003). Pervasive computing: a paradigm for the 21st century. *Computer*, 36(3):25–31. 9

[158] Santos, P. E., Martins, M. F., Fenelon, V., Cozman, F. G., and Dee, H. M. (2016). Probabilistic self-localisation on a qualitative map based on occlusions. *J. of Experimental & Theoretical Artificial Intelligence*, 28(5):781–799. 35, 39

[159] Satyanarayanan, M. et al. (2001). Pervasive computing: Vision and challenges. *IEEE Personal communications*, 8(4):10–17. 9

[160] Schwenk, M., Mohler, J., Wendel, C., Fain, M., Taylor-Piliae, R., Najafi, B., et al. (2015). Wearable sensor-based in-home assessment of gait, balance, and physical activity for discrimination of frailty status: baseline results of the arizona frailty cohort study. *Gerontology*, 61(3):258–267. 40

[161] Shanahan, M. (1999). The event calculus explained. In *Artificial intelligence today*, pages 409–430. Springer. 33, 77

[162] Shimokawara, E., Kaneko, T., Yamaguchi, T., Mizukawa, M., and Matsuhira, N. (2013). Estimation of basic activities of daily living using zigbee 3d accelerometer sensor network. In *ICBAKE*, pages 251–256. IEEE. 3, 12, 14

[163] Shnayder, V., Chen, B.-r., Lorincz, K., Fulford-Jones, T. R., and Welsh, M. (2005). Sensor networks for medical care. 40

[164] Siegert, R. J. and Turner-Stokes, L. (2010). Psychometric evaluation of the northwick park dependency scale. *Journal of rehabilitation medicine*, 42(10):936–943. 19

[165] S.L., L. M. S. (2019). MySignals - eHealth and Medical IoT Development Platform. Technical Guide. http://www.libelium.com/downloads/documentation/mysignals_technical_guide.pdf. 40, 77

[166] Sprinkle, J., Mernik, M., Tolvanen, J.-P., and Spinellis, D. (2009). Guest editors' introduction: What kinds of nails need a domain-specific hammer? *IEEE software*, 26(4):15–18. 26

[167] Stanford, V. (2002). Using pervasive computing to deliver elder care. *IEEE pervasive computing*, 1(1):10–13. 2

[168] Stankovski, V. and Trnkoczy, J. (2006). Application of decision trees to smart homes. In *Designing smart homes*, pages 132–145. Springer. 16

[169] Stikic, M., Huynh, T., Van Laerhoven, K., and Schiele, B. (2008). Adl recognition based on the combination of rfid and accelerometer sensing. In *2008 second international conference on pervasive computing technologies for healthcare*, pages 258–263. IEEE. 12

[170] Suryadevara, N. K. and Mukhopadhyay, S. C. (2012). Wireless sensor network based home monitoring system for wellness determination of elderly. *IEEE Sensor Journal*, 12(6):1965–1972. 3, 12, 14

[171] Suryadevara, N. K., Mukhopadhyay, S. C., Wang, R., and Rayudu, R. (2013). Forecasting the behavior of an elderly using wireless sensors data in a smart home. *Engineering Applications of Artificial Intelligence*, 26(10):2641–2652. 15

[172] Takabi, H., Amini, M., and Jalili, R. (2007). Enhancing role-based access control model through fuzzy relations. In *Third International Symposium on Information Assurance and Security*, pages 131–136. IEEE. 17

[173] Tapia, E. M., Intille, S. S., Haskell, W., Larson, K., Wright, J., King, A., and Friedman, R. (2007). Real-time recognition of physical activities and their intensities using wireless accelerometers and a heart rate monitor. 15

[174] Tapia, E. M., Intille, S. S., and Larson, K. (2004). Activity recognition in the home using simple and ubiquitous sensors. In *International conference on pervasive computing*, pages 158–175. Springer. 15

[175] Turner-Stokes, L., Paul, S., and Williams, H. (2006). Efficiency of specialist rehabilitation in reducing dependency and costs of continuing care for adults with complex acquired brain injuries. *Journal of Neurology, Neurosurgery & Psychiatry*, 77(5):634–639. 19

[176] Turner-Stokes, L., Tonge, P., Nyein, K., Hunter, M., Nielsona, S., and Robinson, I. (1998). The northwick park dependency score (npds): a measure of nursing dependency in rehabilitation. *Clinical Rehabilitation*, 12(4):304–318. 19, 77

[177] Vainio, A.-M., Valtonen, M., and Vanhala, J. (2008). Proactive fuzzy control and adaptation methods for smart homes. *IEEE Intelligent Systems*, 23(2):42–49. 17

[178] Van Deursen, A. and Klint, P. (2002). Domain-specific language design requires feature descriptions. *Journal of Computing and Information Technology*, 10(1):1–17. 26

[179] Van Deursen, A., Klint, P., and Visser, J. (2000). Domain-specific languages: An annotated bibliography. *ACM Sigplan Notices*, 35(6):26–36. 37

[180] Van Eenoo, L., van der Roest, H., Onder, G., Finne-Soveri, H., Garms-Homolova, V., Jonsson, P. V., Draisma, S., van Hout, H., and Declercq, A. (2018). Organizational home care models across europe: A cross sectional study. *International journal of nursing studies*, 77:39–45. 8

[181] van Kasteren, T. L., Englebienne, G., and Kröse, B. J. (2011). Hierarchical activity recognition using automatically clustered actions. In *International Joint Conference on Ambient Intelligence*, pages 82–91. Springer. 12, 13

[182] Varshney, U. (2003). Pervasive healthcare. *Computer*, 36(12):138–140. 1, 2

[183] Vildjiounaite, E. and Kallio, S. (2007). A layered approach to context-dependent user modelling. In *European Conference on Information Retrieval*, pages 749–752. Springer. 4

[184] Vogel, T. (2018). *Model-driven engineering of self-adaptive software*. PhD thesis, Universität Potsdam. 26

[185] Volanschi, N., Serpette, B., Carteron, A., and Consel, C. (2018). A language for online state processing of binary sensors, applied to ambient assisted living. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*, 2(4):192. 31, 32, 75

[186] Wallace, M. and Stamou, G. (2002). Towards a context aware mining of user interests for consumption of multimedia documents. In *Proceedings. IEEE International Conference on Multimedia and Expo*, volume 1, pages 733–736. IEEE. 16

[187] Wan, D. and Taveras, L. E. (2006). The business of pervasive healthcare. In *Pervasive Computing in Healthcare*, pages 301–324. CRC Press. 9

[188] Yan, Z., Subbaraju, V., Chakraborty, D., Misra, A., and Aberer, K. (2012). Energy-efficient continuous activity recognition on mobile phones: An activity-adaptive approach. In *2012 16th international symposium on wearable computers*, pages 17–24. IEEE. 11

[189] Yatani, K. and Truong, K. N. (2012). Bodyscope: a wearable acoustic sensor for activity recognition. In *Proceedings of the 2012 ACM Conference on Ubiquitous Computing*, pages 341–350. ACM. 12, 13

[190] Ye, J., Dobson, S., and McKeever, S. (2012). Situation identification techniques in pervasive computing: A review. *Pervasive and mobile computing*, 8(1):36–66. 33

[191] Yuan, B. (2014). Context-aware real-time assistant architecture for pervasive healthcare. 17

[192] Yuan, B. and Herbert, J. (2014). Context-aware hybrid reasoning framework for pervasive healthcare. *Personal and ubiquitous computing*, 18(4):865–881. 3, 12, 14, 15, 35, 39, 60

[193] Zadeh, L. A. (1975a). The concept of a linguistic variable and its application to approximate reasoning-i, ii, iii. *Information Science*, 8. 17

[194] Zadeh, L. A. (1975b). Fuzzy logic and approximate reasoning. *Synthese*, 30(3-4):407–428. 17

[195] Zeifman, M. and Roth, K. (2011). Nonintrusive appliance load monitoring: Review and outlook. *IEEE transactions on Consumer Electronics*, 57(1):76–84. 15

[196] Zhang, J., Song, G., Wang, H., and Meng, T. (2011). Design of a wireless sensor network based monitoring system for home automation. In *2011 International Conference on Future Computer Sciences and Application*, pages 57–60. IEEE. 15

[197] Ziekow, H., Goebel, C., Strüker, J., and Jacobsen, H.-A. (2013). The potential of smart home sensors in forecasting household electricity demand. In *2013 IEEE International Conference on Smart Grid Communications (SmartGridComm)*, pages 229–234. IEEE. 15

Résumé

In recent years, the elderly population sector has increased faster than in the previous decades. In addition to that, elderly population suffers from age-related health issues and different chronic diseases. Furthermore, various studies indicate that the vast majority of elderly people are willing to live independently in their own homes as long as possible.

In order to assess the abovementioned problem, personal sensor networks and body sensor networks in smart environments represent an option regarding healthcare solutions for monitoring elderly people at home.

However, despite their popularity, the abscence of a monitoring approch with regard to a dependency evaluation model such as the AGGIR (Autonomie Grontologie Groupes Iso-Ressources) grid variables has never been treated.

Therefore, in this thesis work, with the aim of providing an analyis tool regarding the monitoring of ADL's performed by the elderly/handicapped people within a home environment by means of data recovered from sensors; a Domain Specific Language (DSL) relying on the AGGIR grid model is proposed.

The main contributions of this research work are:

- A state-of-the-art related to the proposed subject;
- A Domain Specic Language (DSL) for assessing the AGGIR grid variables;
- A framework for validating the proposed DSL.

For the purpose of determining the ADL's carried out by the elderly resident, as well as recognising the AGGIR grid variables; the introduced DSL is based on both temporal and location operators.

Moreover, with the goal to validate the abovementioned DSL, a framework architecture is presented in order to meet the requirements for analyzing complex events. To this extent, the framework is conformed by: (i) the DSL as its main component, (ii) the integration of the proposed DSL to a smart-home simulator for performing evaluation and experimentation; (iii) a parser aimed to process the data recovered from the DSL in order to generate appropriate instructions for the smart-home simulator.

Mots-clés: Domain Specific Language, Feature-oriented Programming, Pervasive Computing, Pervasive Health Systems and Services, AGGIR grid

Abstract

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Keywords: Domain Specific Language, Feature-oriented Programming, Pervasive Computing, Pervasive Health Systems and Services, AGGIR grid

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