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Evolutionary Service Composition and Personalization Ecosystem for Elderly Care

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To the ones I love

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Abstract

Current demographic trends suggest that people are living longer, while the ageing process entails many necessities, calling for care services tailored to the individual senior's needs and life style. Personalized provision of care services usually involves a number of stakeholders, including relatives, friends, caregivers, professional assistance organizations, enterprises, and other support entities. Traditional Information and Communication Technology based care and assistance services for the elderly have been mainly focused on the development of isolated and generic services, considering a single service provider, and excessively featuring a techno-centric approach.

In contrast, advances on collaborative networks for elderly care suggest the integration of services from multiple providers, encouraging collaboration as a way to provide better personalized services. This approach requires a support system to manage the personalization process and allow ranking the {service, provider} pairs.

An additional issue is the problem of service evolution, as individual's care needs are not static over time. Consequently, the care services need to evolve accordingly to keep the elderly's requirements satisfied. In accordance with these requirements, an Elderly Care Ecosystem (ECE) framework, a Service Composition and Personalization Environment (SCoPE), and a Service Evolution Environment (SEvol) are proposed.

The ECE framework provides the context for the personalization and evolution methods. The SCoPE method is based on the match between the customer´s profile and the available {service, provider} pairs to identify suitable services and corresponding providers to attend the needs. SEvol is a method to build an adaptive and evolutionary system based on the MAPE-K methodology supporting the solution evolution to cope with the elderly's new life stages.

To demonstrate the feasibility, utility and applicability of SCoPE and SEvol, a number of methods and algorithms are presented, and illustrative scenarios are introduced in which {service, provider} pairs are ranked based on a multidimensional assessment method. Composition strategies are based on customer’s profile and requirements, and the evolutionary solution is determined considering customer’s inputs and evolution plans.

For the ECE evaluation process the following steps are adopted: (i) feature selection and software prototype development; (ii) detailing the ECE framework validation based on applicability and utility parameters; (iii) development of a case study illustrating a typical scenario involving an elderly and her care needs; and (iv) performing a survey based on a modified version of the technology acceptance model (TAM), considering three contexts: *Technological*, *Organizational* and *Collaborative environment.*

Keywords: Collaborative Business Services, ICT and Ageing, Elderly Care, Collaborative Networks, Service Personalization and Evolution.

Resumo

As tendências demográficas atuais sugerem que as pessoas estão vivendo mais, enquanto o processo de envelhecimento envolve muitas necessidades, exigindo serviços de atendimento adequados às necessidades e ao estilo de vida do idoso. O fornecimento personalizado de serviços de assistência geralmente envolve várias partes interessadas, incluindo parentes, amigos, cuidadores, organizações de assistência profissional, empresas e outras entidades de apoio. Os serviços tradicionais de cuidados e assistência baseados em tecnologia da informação e comunicação para os idosos têm se concentrado principalmente no desenvolvimento de serviços isolados e genéricos, considerando um único prestador de serviços, e apresentando uma abordagem tecno-cêntrica excessiva.

Em contrapartida, os avanços nas redes colaborativas de atendimento ao idoso sugerem a integração de serviços de múltiplos provedores, incentivando a colaboração como forma de oferecer melhores serviços personalizados. Essa abordagem requer um sistema de suporte para gerenciar o processo de personalização e permitir a classificação dos pares {serviço, provedor}.

Uma questão adicional é o problema da evolução do serviço, pois as necessidades de cuidado do indivíduo não são estáticas ao longo do tempo. Consequentemente, os serviços de cuidados precisam evoluir de acordo para manter os requisitos dos idosos satisfeitos. De acordo com esses requisitos, uma estrutura ECE (Ecosistema de Cuidado para Idosos), um SCoPE (Ambiente de Composição e Personalização do Serviço) e um SEvol (Ambiente de Evolução do Serviço) são propostos.

O ECE fornece o contexto para os métodos de personalização e evolução. O método SCoPE é baseado na correspondência entre o perfil do cliente e os pares {serviço, provedor} disponíveis para identificar serviços adequados e provedores

correspondentes para atender às necessidades. O SEvol é um método para construir um sistema adaptativo e evolutivo baseado no Metodologia MAPE-K apoiando a evolução da solução para lidar com as novas fases da vida do idoso.

Para demonstrar a viabilidade, utilidade e aplicabilidade do SCoPE e do SEvol, são apresentados vários métodos e algoritmos, e são apresentados cenários ilustrativos nos quais os pares {serviço, provedor} são classificados com base em um método de avaliação multidimensional. As estratégias de composição são baseadas no perfil e nos requisitos do cliente, e a solução evolucionária é determinada considerando os insumos e os planos de evolução do cliente.

Para o processo de avaliação da ECE, são adotadas as seguintes etapas: (i) seleção de recursos e desenvolvimento de protótipos de software; (ii) detalhar a validação da estrutura do ECE com base em parâmetros de aplicabilidade e utilidade; (iii) desenvolvimento de um estudo de caso ilustrando um cenário típico envolvendo um idoso e suas necessidades de cuidado; e (iv) realizar um levantamento baseado em uma versão modificada do modelo de aceitação de tecnologia (TAM), considerando três contextos: Ambiente Tecnológico, Organizacional e Colaborativo.

Palavras-chave: Serviços de Negócios Colaborativos, Tecnologia e Envelhecimento, Cuidado para Idosos, Redes Colaborativas, Personalização e Evolução de Serviços.

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ECE	Elderly Care Ecosystem
ICT	Information and Communication Technology
IoT	Internet-of-Things
CU	Customer
SE	Service
SP	Service Provider
CA	Care Need
AD	Service Adherence

1

Introduction

The aim of this chapter is to introduce the topic of this research work. First the problem statement and motivation are presented, followed by the research question and corresponding hypothesis. Then the research context of the work is introduced, and the adopted research method is shortly described. It finishes with an outline of this dissertation.

1.1 Problem Statement and Motivation

Recent studies in the field of aging indicate that the percentage of seniors' population worldwide is constantly growing (Fengler, 2014; Gartner, 2018; Kearney, 2013). In Europe, elderly population already represents 24% of the population (175 million persons), in contrast to 16% of youngsters (117 millions)(Gartner, 2018). While it is expected that the general Europe's population decreases over the years, current trends indicates that the percentage of seniors will reach rates of 27.2% of the population by 2050 (Bureau, 2018).

The common practice of designating people older than 65 as "old" began in Germany in the 1880s, when Otto von Bismarck selected 65 as the starting age for certain social welfare benefits (Thakur et al., 2013). Nowadays, the World Health Organization1 (WHO) classifies chronologically older people over the age of 65

[1]http://www.who.int/en/

in developed countries, and over 60 years old in developing countries. To geriatrics, the branch of medicine that focuses on the study, prevention and treatment of diseases and disabilities in old age, a person is only considered in the old age after completing 75 years (WorldHealthOrganization, 2010, 2018).

Currently, divisions may be made between the young-old and the old-old (younger and older than 75, respectively), or between these groups and the oldest old (generally 85 years and older). Although these distinctions are also arbitrary, they can be useful in identifying important differences in terms of capabilities levels and can help avoiding overgeneralization about characteristics of older adults. It is also important to keep in mind that individuals may age faster in some dimensions than others (e.g., being "old" physically but youthful psychologically or socially) (Park & Reuter-Lorenz, 2009).

Age-related changes affecting perceptual capabilities (such as vision or hearing) and motor skills are especially problematic for older adults. Biological factors like physiological and cognitive declination are often strong causes for the loss of autonomy, and for physical limitations. In extreme cases, regular daily activities such as cooking, performing personal hygiene, housework's, etc., are often affected (Thakur et al., 2013).

Despite this reality, it is estimated that 60% of elderly people live by themselves or in the company of another elderly person and strive to guarantee their autonomy and perform their own duties. With the continuous advances in medicine and wellness areas, people aspire to an active and enjoyable aging (Kearney, 2013) although aging might as well entail several limitations due to impairments (Thakur et al., 2013).

The traditional way to deal with this problem requires intense care from family. Relatives need to actively participate in the aging process and support elderly. In this case, many people live with their family when they begin to lose capabilities. Those who remain living by themselves either care for themselves alone or require caregivers to assist them on daily activities. Alternatively, the elderly may stay in a nursing home. All these changes, can directly affect the senior´s life style (Thakur et al., 2013). The experience of aging can make people more demanding and grumpier, as they may not like this new lifestyle, or find that they are considered a burden to the family, suffering from depression and sadness moments. In this context, aging is a process that requires dedication of time (attention care from family) and financial resources.

With aging, when the objective is to keep seniors healthy and enjoying a high quality of life, specific care needs appear. Each individual elderly person may require focused services (e.g., care and assistance) according to his/her life context. In fact, characterizing a person as elderly involves more than age as a determinant factor. Singular elements of the aging process, such as life settings, individual capacities, and abilities, contribute to characterize an elderly person. As a result, a specific care service might be enough for an individual and very futile for another. This brings up the necessity of personalized and composite services in this sector.

The notion of personalized service typically involves a composition of various basic services, possibly offered by different providers, which together fit the needs of each individual (Baldissera et al., 2017b; Evenson & Dubberly, 2010; Hong et al., 2009; Lee, 2007). Therefore, customizing a (composite) service includes an understanding amongst customer and suppliers (and all other involved stakeholders) through which they share data to allow an adequate adaptation of the service offer (Baldissera et al., 2017a; Kwortnik Jr et al., 2009; Manoharan et al., 2015).

The idea of a collaborative business environment for elderly care can help on the integration of various services from different service providers (Afsarmanesh et al., 2012; Baldissera & Camarinha-Matos, 2016a; Camarinha-Matos et al., 2015). Likewise, finding the set of services and corresponding service providers that best cover the senior's lifestyle, needs, and desires is a challenge.

Although related approaches can be found in the literature, there is a lack of a comprehensive framework that manages the process of service composition and evolution for elderly care in a collaborative environment. Also, keep the service always adapted to the constant changes in lifestyle is a factor that adds more difficulty in overcoming this challenge (personalization and evolution of the service).

In this context, the main aim of this thesis is to devise an approach for the provision of personalized and evolutionary services for elderly care in an efficient and reliable way, respecting the individuality and reality of each elderly and his/her life stage.

1.2 Research Question and Hypothesis

Taking into consideration the requirements of provision of collaborative business services for elderly, important questions are how can this process be improved and what are the main issues that companies and organizations face when providing personalized collaborative care and assistance services for elderly?

More specifically, personalized services depend on continuous contextual information analysis, and efficient service adaptation requires fitness analysis. These aspects are particularly important as "standard one-fits-all" care services do not fully cope with elderly needs. Furthermore, care services need to be integrated and smoothly adapted to the evolution of needs as the person progressively loses capabilities while aging.

Therefore, the main research question that emerges is:

How to provide personalized and evolutive collaborative care services for elderly in an effective and reliable way?

The hypothesis adopted for this work is:

Effective and reliable personalized and evolutionary services for elderly care can be provided if a suitable set of multi-provider business services are composed and integrated in the context of a collaborative network environment and supported by context awareness methods, mechanisms and systems.

1.3 Research Context: Aging-related Projects

This work was carried out in the Collaborative Networks and Distributed System (CODIS) group which focuses its research activities on the understanding (principles and models) and support (methods, tools, and technologies) for collaborative networks and distributed architectures and systems applied to industry and services.

Participating in this group, it was possible to get access to material produced (and often unpublished) in the projects in which the group participated, such as partial reports, final reports, meeting notes, bibliographic surveys, etc. The background of collaborative networks and the aging process obtained through the analysis of these materials was fundamental to the development of this dissertation. Following the relevant projects are briefly presented with the main contribution for the thesis.

TeleCARE. The TeleCARE (*A multi-Agent Tele-Supervision System for Elderly Care*) project was funded by the European Commission under the 5th Framework Programme (IST-2000 – 27607, 2000-2004). The project's main objective was the design and development of a framework for tele-supervision and tele-assistance, following a federated multi-agent system approach, with the goal of assisting elderly people at their home environment (Camarinha-Matos & Afsarmanesh, 2004). It also included services to support elderly relatives and elderly care centers in the monitoring and assistance of elderly people.

Main contribution. This project provide a first contact with the concepts of collaborative networks and virtual communities involving people, companies, and devices/software agents over the Internet.

ePAL. The ePAL (*extending Professional Active Live*) project was funded by the European Commission under the 7th Framework Programme (ICT-2007.7.1 – 215289, 2008-2010). This was a coordination action project aimed at developing a strategic research roadmap focused on identifying innovative ways that best facilitate the development of active life process for retiring and retired professionals promoting at the same time, the notion of silver economy (Camarinha-Matos & Afsarmanesh, 2010). It identified a set of recommended actions covering societal, organizational, and technological perspectives.

Main contribution. The interaction with senior professionals and networks of retired professionals which leveraged the design and implementation of innovative solutions and new organizational forms for collaborative networks.

BRAID. The BRAID (*Bridging Research in Ageing and ICT Development*) project was funded by the European Commission under the 7th Framework Programme (ICT 2009-7.1 – 2484852, 2010-2012). This was a supporting action project aimed at developing a comprehensive research and technological development roadmap for active ageing. This RTD agenda, which joined previous roadmap initiatives results, namely from AALIANCE, CAPSIL, ePAL, and SENIOR projects, defined a new and common strategic research agenda to support the socio-economic integration and wellbeing of senior citizens, and consolidate and re-enforce EU leadership in ICT and ageing (Afsarmanesh et al., 2011; Camarinha-Matos et al., 2013a).

Main contribution. The new knowledge and embraced new challenges concerning different perspectives of life settings for seniors, such as independent living, health and care in life, occupation in life, and recreation in life. In addition, new challenges for the socio-technical aspects of collaborative networks were identified.

AAL4ALL. The AAL4ALL (*Ambient Assisted Living for All*) project was an anchor project of the Health Cluster Portugal (*Pólo de Competitividade da Saúde*) and was funded by the Portuguese Government through the *COMPETE* Programme from the *Quadro de Referência Estratégica Nacional* (QREN-COMPETE 2011-2015). The main objective of the AAL4ALL project was to develop a large-scale ecosystem with products and ambient assisted living services to support elderly people and maintain them at their preferred environments (Camarinha-Matos et al., 2012b). The project considered the scenarios elaborated in the BRAID project and implemented a large-scale pilot.

Main contribution. With the participation (for almost two years) in this project the accumulated knowledge comprising CNs and the interaction with the project partners' views also contributed to the consolidation of this thesis work.

1.4 Research Design

The main branches of research design include (Pedersen et al., 2000) Exploratory Research, Constructive Research, and Empirical Research. Exploratory research is important to research methods because it helps define a new problem or question. It is used to determine concept testing, which is important to know before releasing new products on the market. The Constructive Research encompasses the area of theory, and is more based upon theories, hypotheses, and case studies. It is used to design science. Empirical Research is based more reality experiments. It will prove the theory with both direct and indirect forms of observation and analysis.

One important step in a research work is its validation. However, validation and verification have particularities according to the research area and the research design. In what concerns the CNs area it focuses on socio-technical systems and "*it is well known that is difficult to implement any (short term) validation process when we are dealing with these kinds of systems*" (Macedo, 2011). Frequently, a mix of research methods are used to validate the expected results (Pedersen et al., 2000).

The Constructive Research method (Kasanen et al., 1993) adapted by Macedo (2011) can help in validating applied research in the area of design science, through the building of one or more artefacts that solve a domain problem, in order to create knowledge on how the problem can be solved, and how the solution is new or better than the previous ones.

The constructive approach may be characterized by dividing the research process into the following phases (Kasanen et al., 1993):

1. Find a practically relevant problem which also has research potential;

2. Obtain a general and comprehensive understanding of the topic;

3. Innovate, i.e., construct a solution idea (one or more artefacts);

4. Demonstrate that the solution works (software prototype);

5. Show the theoretical connections and the research contribution of the solution concept;

6. Examine the scope of applicability of the solution.

The main research work in this thesis positions itself in design science scope and will thus use the constructive research approach. Nevertheless, the constructive research process can be considered as an adaptation of the traditional scientific research process, since it follows its main steps, as it can be observed in the Figure 1.1.

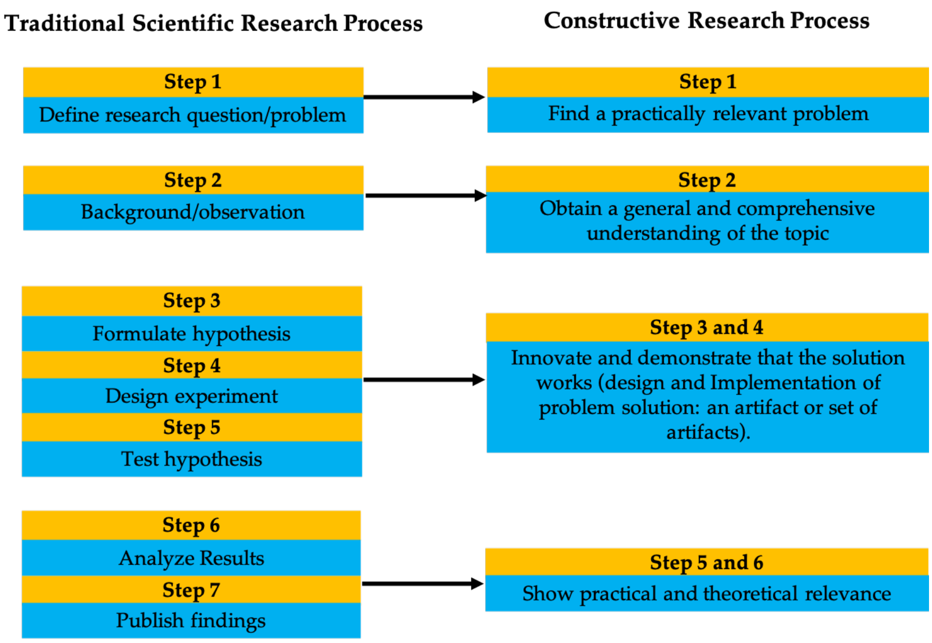


Figure 1.1: Traditional scientific research process versus Constructive Research method

The steps of the constructive research method are detailed in the following:

Step 1 – Find a practically relevant problem. Considering the changing demographic evolution and the aging population, it is necessary to prepare society for this new reality, as well as to provide to elderly conditions for an active and independent aging. We propose an elderly care ecosystem that aims at respecting the senior individual profile and providing the personalized and evolutive collaborative care services.

Step 2 – Obtain general and comprehensive understanding of the topic. The research is supported on the body of knowledge of the Collaborative Networks discipline (Camarinha-Matos & Afsarmanesh, 2008c) and focuses on providing methods and tools that contribute to the service composition and evolution in the collaborative environments. While service composition plays a fundamental role during the construction of virtual organizations, evolution aims to achieve better solutions over time, considering changes occurring in the lifestyle of elderly, in the environment, or in the care business itself.

Steps 3 e 4 – Innovate and demonstrate that the solution works. In order to give answers to the proposed research question, the adopted approach aims to develop a collaborative elderly care ecosystem able to provide personalized and evolutionary services. The following main elements comprise this approach:

Modelling design:

- Development of Elderly Care Ecosystem - ECE conceptual framework and related definitions (Chapter 3).

Methods and mechanisms for personalization and evolution of services:

- Service Composition Personalization Environment — SCoPE method for perceiving and classifying services (Chapter 4).

- Service Evolution Environment – SEvol method for services evolution based on the life stage of the customer (Chapter 5)

Tools: ECE software prototype

- Software system to support personalized and evolutive services. I.e. to support the provision of personalized and evolutive services through a collaborative business ecosystem for elderly care (Chapter 6).

Step 5 e 6 – Show practical and theoretical relevance. The artificial artefacts serve human purposes and the proposed problem solution (ECE conceptual framework, methods and mechanisms for personalization and evolution of services, and the prototype system) try to give an appropriate answer to the formulated research question.

The theoretical relevance of the proposed models and methods is argued through explanation and discussion of the contribution that these artefacts give to the following bodies of knowledge: collaborative networks, collaborative business ecosystem, service personalization, and service evolution. The ECE framework, the ECE personalization, and ECE evolution processes are evaluated in terms of their applicability and utility considering Saunders (2011) recommendations and the Technology Acceptance Model (TAM) methodology, adapted from Davis et al. (1989).

The scientific contribution is also validated through the acceptance of the developed work and the corresponding results in International Journals and Conferences indexed in the Web of Science or Scopus.

The practical relevance is demonstrated through the collection of evidence that shows that the proposed artefacts can be applied in real contexts, bringing new information to support decision-makers: simulation and formulation of case studies. In laboratory (experiment) and in real situation through interactions with elderly care services organizations (e.g. Home Angels and Comfort Keepers) with a survey-based experiment.

More details about the practical and theoretical relevance and how this work validation is carried out are presented in Chapter 6.

1.5 Thesis Outline

This dissertation is organized into seven chapters. A brief abstract of each chapter is presented in order to give an overview of this dissertation document.

Chapter 1 - Introduction. The current chapter. It begins with the problem statement and motivation, followed by the research question and hypothesis. Then the research context of the work is introduced, and the adopted research method is shortly described. It finishes with this overview of the outline of this dissertation.

Chapter 2 – Background and Literature Review. This chapter introduces the concepts needed to better sustain the challenges of this research work. An overview of the main concepts about the demographic evolution and the aging process is introduced, followed by a brief discussion on the collaborative networks environment and potential technologies for aging support to provision the personalized and evolutionary service, and analysis of the current research work in the thesis area.

Chapter 3 – Elderly Care Ecosystem. This chapter proposes a conceptual model for the Elderly Care Ecosystem (ECE) framework. First the ECE concepts and relationships, and a generic template of customer (elderly) profile, care need profile, service profile and service provider profile, are presented using UML class diagrams and descriptions using natural language. Then a formalization of the model is presented to provide more accurate definitions of the main concepts and relations used during the service composition and personalization processes.

Chapter 4 – Service Personalization System: SCoPE Method. This chapter presents the approach to the Service Composition and Personalization

Environment (SCoPE). Related aspects of the ECE environment are described and a customer profile template is proposed in the context of the collaborative networks domain. Then, SCoPE is presented highlighting its key steps: scope filtering, service adherence calculation, and service rating and composition. For this purpose, various methods and algorithms are introduced, and a practical application case is discussed throughout the chapter.

Chapter 5 – Service Evolution System: SEvol Method. This chapter presents an adaptive system´s approach for service evolution in the scope of ECE. An evolutionary and adaptive system and the SEvol method, based on MAPE-k control loop structure, are described. Then, the Service Evolution specific model is introduced and the solution evolution loop within ECE is detailed. A workflow diagram is presented considering the main ECE´s processes and their interactions demonstrating the ECE environments and ECE phases of execution.

Chapter 6 – ECE Evaluation. This chapter presents the evaluation process of ECE framework. The approach to validation methodology is introduced in two stages: (i) the evaluation of the ECE conceptual framework, the ECE Personalization System, and ECE Evolution System through case studies, prototype implementation, survey and simulations, and (ii) evaluation of the ECE framework through the acceptance by the research community considering panels, presentations, and publications. This chapter finishes with the results analysis.

Chapter 7 – Conclusions and Future Work. This chapter presents a summary of the findings and concludes the thesis. The work analysis is discussed and the chapter finishes with presentation of further research challenges found during this thesis, and thus outlines various open issues established for future work.

2

Background and Literature Review

The aim of this chapter is to present the body of knowledge that nourishes the work developed in this thesis. It starts by introducing the background on aging process, highlighting the population demographic evolution, aging care needs and elderly social changes. Then it presents the collaborative networks environment, the main concepts and definitions applied in the research, such as business ecosystem, service composition, service personalization and service evolution. Finally, a summary shows the main relations among the background, the literature review, and this research work.

2.1 Aging Process

2.1.1 Population Demographic Evolution

Current trends suggest that the percentage of the elderly population is increasing significantly (Fengler, 2014; Gartner, 2018; Kearney, 2013). In continents, such as Europe, the current proportion of elderly is around 24% of the population, corresponding approximately to 175 million people, while young people are around 117 million (16%). In 2050, although Europe´s population tends to decrease, the number of seniors is expected to reach 27.2% of the population (Bureau, 2018). Such trends show that the population are living longer, staying healthy for more time, and consequently working for more years (Kearney (2013), (Bureau, 2018) and (WorldHealthOrganization, 2018). On the other hand, the number of births has declined worldwide in the past 20 years. The number of born alive babies reached 90 million in 1989. In 2010 only 73 million babies were born, and the trajectory has been moving steadily downward. Figure 2.1 (a) shows the total fertility rate in various continents, comparing the situation in 1970 with 2017. In 1970, each woman had 4.2 children on average in the world, while in 2017, this number decreases to 2.4. The same trend can be observed in all continents, reaching a dramatic situation in the case of Asia and Latin America and Caribbean. In these two regions, there is a clearly low-level demographic sustainability.

Another relevant trend, with an opposite effect, is the decrease in infant mortality. Figure 2.1 (b) shows the infant mortality rate in the world, and continents, comparing 1970 and 2017. A relevant aspect shown in this chart is the drastic reduction of infant death per 1,000 births over the years. While 68 children would not survive in 1970 per 1000 births, this number is reduced to 21 in 2017. This fact represents a decrease of 69% in infant deaths, which is proportionally observed in all continents. Nevertheless, this reduction does not compensate for the decrease in the fertility rate.

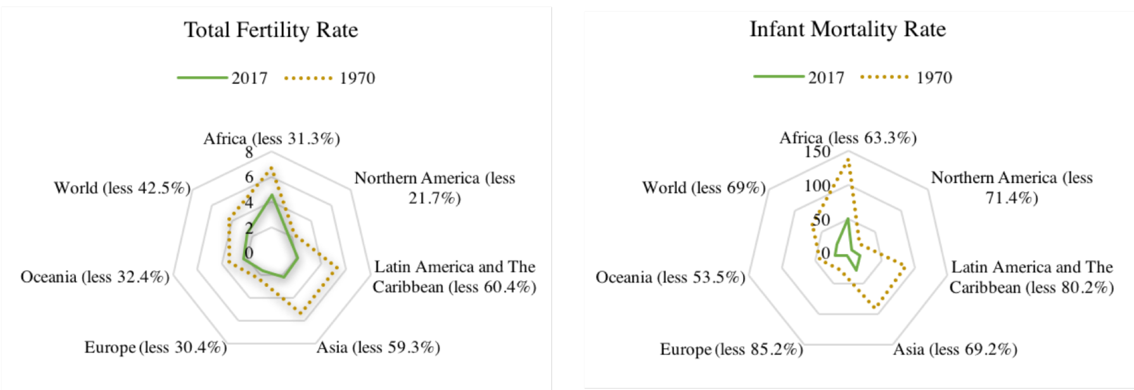
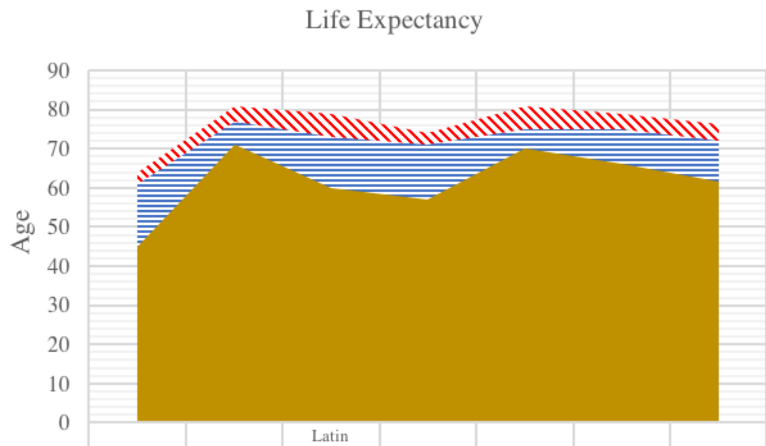


Figure 2.1: (a) Total Fertility Rate and (b) Infant Mortality Rate in the World and Continents. Adapted from (Bureau, 2018)

The continuous progress in medicine (treatment, devices, products) contributes to prolonging life, even though some indicators (Kearney, 2013) suggest that obesity and unhealthy food could eventually shorten the steady improvement in longevity. Also, the nature of aging has changed. Healthy life expectancy is increasing rapidly in the world, by approximately one year every five years (Chiarini et al., 2013; WorldHealthOrganization, 2018). Once an adult has reached the age of 60, she/he can expect, on average, 13 more years of full health. This trend can be observed in Figure 2.2, where the life expectancy in the

World has grown 24% to women (14 years) and 17% to man (10 years) from 1970 to 2018. In all continents, this situation is similar. In the last decades, people are more active and healthier into their 70s and 80s, traveling abroad, dining out, and spending a higher proportion of their incomes on food and drink than those under 60 (Bureau, 2018; Cresci et al., 2010; Enterprise, 2015).

On average, the society is getting old due to the increase in the average life expectancy from 62 to 74 years old. In this way, this age group represents a bigger slice in the total number of the population. This situation also can be seen with the increase of the world average age, from 24 years old in 1950 to 29 in 2010, 32 in 2025 and 36 in 2050 (Bureau, 2018).



	Africa	Northern America	Latin America and The Caribbean	Asia	Europe	Oceania	World
2017 (female)	64	81	79	74	81	79	76
2017 (male)	61	77	73	71	75	75	72
1970	45	71	60	57	70	66	62

Figure 2.2: Life Expectancy in the World and Continents. Adapted from Bureau (2018)

For years the proportion of people older than 60 in the workforce has declined (Munnell, 2011), but this scenario has been reversed and is sharply rising in developed countries, partially in response to changes in legal retirement ages and changing pension regulations due to the economic crisis and increase of elderly population (HelpAgeInternational, 2018). In Portugal, for instance, labor force participation rates among men aged 65 or older declined between 1980 and 1990 but increased by 3 to 11 percent between 1990 and 2009 (INEA, 2015).

Today, the fastest-growing age group in the workforce in many countries is people aged 65 to 74 (Bureau, 2018; Kearney, 2013). This trend is expected to be constant and global because it is linked to better financial support after retirement if people work longer (Munnell, 2011). It is a result of a number of aspects influencing decisions to postpone retirement over the past 25 years, such as people living longer and feeling more available to the labor market, studying more (and more-educated people are known to remain employed longer), and holding decision-making positions for which the experience of older people are more relevant (Gartner, 2018; Kearney, 2013).

The reduction of benefits for retirees, the availability of employer-provided health insurance, and the increasing numbers of employed women reaching older ages with longer work histories than previous generations also lead to longer professional careers (Gartner, 2018; Munnell, 2011).

Being an inevitable and widespread phenomenon around the world, the growth of elderly population imposes structural changes in society, with impacts on economic growth, on the labour market, on the capital and consumption, on health systems and social support, and on family structures.

2.1.2 Elderly Care Needs

The basic needs of people can be represented in a synthetic form in the well-known Maslow´s pyramid (Maslow, 1943) (Figure 2.3 shows Maslow´s pyramid and some typical examples of elderly care needs). The most fundamental level of needs is placed at the bottom of the pyramid while the need of self-actualization is located on top. Maslow's model suggests that the most basic level of needs must be met before the individual desires (or focuses his/her motivation upon) the secondary or higher level needs. On the other hand, the human behaviour is complex and involves parallel processes running at the same time. In the case of elderly, many different motivations from various levels of Maslow's hierarchy can occur at the same time and evolve with aging.

The aging process is responsible for changes at both biological and psychosocial levels. These age-related changes may impact several distinct aspects of older adults' lives and limit the extent to which they are able to perform certain activities (Kearney, 2013; Saarnio et al., 2017; Weicht, 2013). Physiological needs are the physical requirements for human survival. Age-related changes affecting perceptual capabilities (such as vision or hearing) and motor skills are especially problematic for older adults when trying to interact with actual technologies, like devices' screens and voice commands. Interacting with these technologies is almost mandatory for the daily activities, such as the use of ATMs or entering passwords for payments with credit cards.

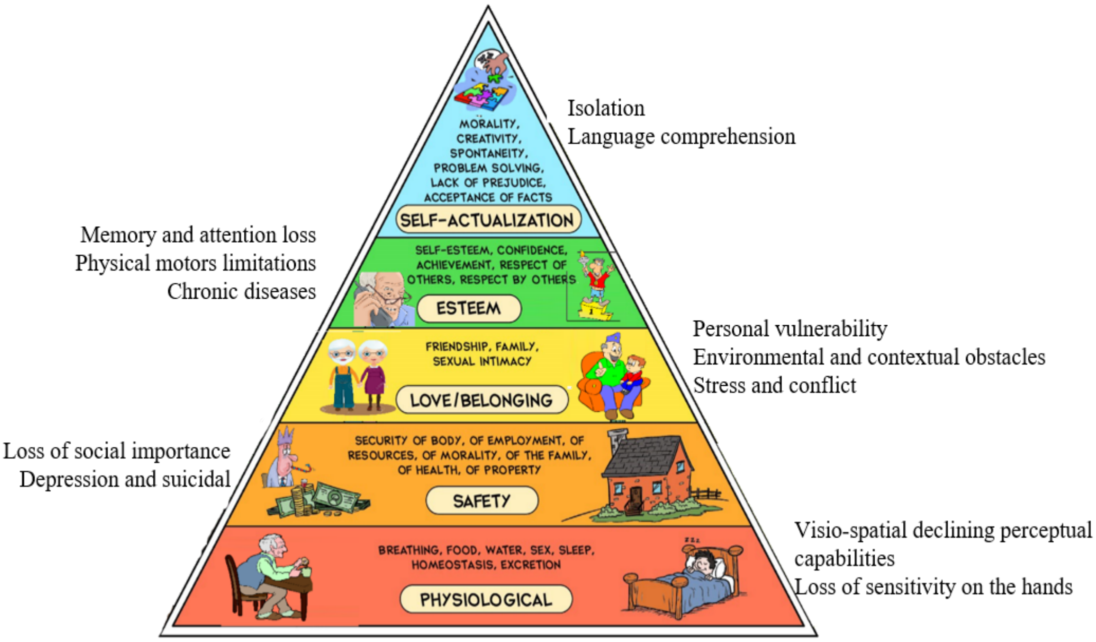


Figure 2.3: Maslow´s Adapted Pyramid

Biological factors such as physiological and cognitive decline are often strong factors for the loss of autonomy (Kearney, 2013; Thakur et al., 2013; Weicht, 2013). Also, physical motor limitations require support for mobility and transportation, and in extreme cases, chronic diseases may affect basic normal daily activities such as cooking, doing personal hygiene, house caring, etc.

Older adults can experience challenges while reading at close distances as a result of a condition known as presbyopia, the inability to focus effectively on near objects (Charness & Jastrzembki, 2009). Transitioning from light to dark environments or performing visual tasks under dim light can also be difficult (Park & Reuter-Lorenz, 2009). In general, seniors also experience a loss of static and dynamic visual acuity and yellowing of the lens, which decreases colour sensitiveness in the blue-to-green ranges (Charness & Jastrzembki, 2009).

Age-related changes in motor skills include slower response times, decrease in the ability to maintain continuous movements, disruptions at coordination, loss of flexibility and variability on movements (Czaja & Lee, 2009). The haptic processes can also suffer some changes, specifically the loss of sensitivity on the hands (Park & Reuter-Lorenz, 2009). These motor skills can greatly influence the perception that individuals to get from interacting with a system.

Safety and security needs include personal security, financial security, health and well-being, a safety net against accidents/illness and their adverse impacts (Saarnio et al., 2017). Also, economic factors can influence directly on active aging, as one needs more money for health care, medicine, and prevention.

The level of human needs is interpersonal and involves feelings of belongingness. This need is especially strong in childhood and aging. The problems are further amplified by the reduction of the elder´s social network. For the older individual, the social component is one of the most important means towards well-being. However, in old ages, there are a number of factors that can inhibit the maintenance of relationships such as the death of friends and family, low-interaction with professional colleagues, personal vulnerability, environmental and contextual obstacles, stress and conflicts (Crispim & de Sousa, 2010). The informal support of networks for the elderly as well as the involvement in social networks can be a good solution to minimize this situation (Camarinha-Matos et al., 2015; Gartner, 2018; HelpAgeInternational, 2018).

All humans need to feel that they are respected; this includes the need of having self-esteem and self-respect. Esteem represents the typical human desire of being accepted and valued by others. Being retired is often associated with a loss of social importance and power due to the disengagement of an active social role (Crispim & de Sousa, 2010; Munnell, 2011). This perceived lack of responsibilities and involvement in the society may induce an identity crisis and consequent loss of self-esteem and the feeling that she/he is a burden to her/his family (Maslow, 1943). Moreover, physical and cognitive changes that affect one's independence and autonomy can have psychologically distressing consequences. These changes can pose threats to one's ability to live safely and independently, leading to depression and the growing of suicidal rates (Kearney, 2013; Park & Reuter-Lorenz, 2009).

Memory and attention are some of the most important cognitive abilities that may suffer declination with aging. The capacity of short-term (or working) memory shows signs of declination with aging, and it is known that this affects many complex everyday tasks such as decision-making, problem-solving and planning of goal-directed behaviours (Park & Reuter-Lorenz, 2009). This situation is mainly due to the challenge older adults face when storing and managing large amounts of new information (Charness & Jastrzembki, 2009). However, unlike the working memory, the long-term memory (or semantic) is largely preserved in old age (Park & Reuter-Lorenz, 2009).

In general, attention is also affected by aging. Older adults have shown to face challenges in tasks that require divided attention across multiple input channels and are also more prone to being distracted by irrelevant information (Charness & Jastrzembki, 2009).

Two other relevant human skills are spatial cognition and language comprehension (Saarnio et al., 2017). The former is related to the ability of mentally manipulating images or patterns whereas the latter is the ability to interpret verbal information (Park & Reuter-Lorenz, 2009). Both these cognitive skills have shown to decline with age, and they can, along with memory and attention, affect the way elders perceive and interpret information.

Even though people tend to be aware of the physical age-related changes, social changes that occur in elder´s life are equally important. These changes are presented in the next section.

In summary, the main changes in aging cover depression, memory loss, attention loss, autonomy loss, physical motors limitations, chronic diseases, visio-spatial declining perceptual capabilities, loss of sensitivity on the hands, decreased hearing, decreased vision, color sensitiveness, loss of flexibility and variability on movements, illness, feelings of belongingness and mental disorders (Saarnio et al., 2017; Weicht, 2013; Zinnikus et al., 2017).

2.1.3 Elderly Social Changes

While main elderly care related initiatives are generally more focused on providing healthcare services to senior citizens with special needs, society needs to recognize the importance of a broader perspective of the aging process. As such, the concept of "active aging" features a better scope of understanding of the elderly needs. Furthermore, the notion of "productive aging" introduces a new perspective regarding the way society often perceives older people (Camarinha-Matos et al., 2013a)

Active and productive aging can be seen as from a new perspective of the concept of "being elderly". Furthermore, it is important to recognize that the economic growth alone will not improve older people's well-being. Instead, specific policies need to address the implications of aging (HelpAgeInternational, 2018; MacAdam, 2008)

Population aging will strain some national budgets. In general, social security systems suggest that elderly who choose to stay longer in the labour market and postpone their retirement generate additional income to contribute to the financing of pensions (Dang et al., 2001; Munnell, 2011). Probably, most young people will work longer than their predecessors. However, it is more difficult to convince employers that they should keep older workers (they are more expensive) in the activity in order to promote the sustainability of the social security systems.

Regarding pension schemes, aging will primarily affect two points: beneficiaries will be more numerous, and they will claim benefits over a much longer period than at present. Countries with extensive social programs targeted to the older population, namely regarding health care and income support programs, find the costs of these programs escalating as the number of eligible recipients grow and the duration of eligibility lengthens. For instance, the group over 65 accounts for at least 50% of the health care costs and their per capita health costs were three to five times higher than the costs for those with less than 65 in 2001 (Dang et al., 2001). Projections of government expenditures show major increases in the share of gross domestic product devoted to social entitlements for elderly population. In some cases, this share more than doubles as a result of population aging (Yusuf et al., 2013).

In some countries, such as Portugal, the legal retirement age was set to adjust according to demographic changes. In 1994 the legal retirement age for both men and women was 65 years, and in 2017 it went to 66 years and three months (PT, 2017). But in many countries the legal retirement age has remained fairly stable, and the fact that many people retire before reaching the official retirement age to take advantage of early retirement incentives can further worsen the economic situation of the country (Yusuf et al., 2013).

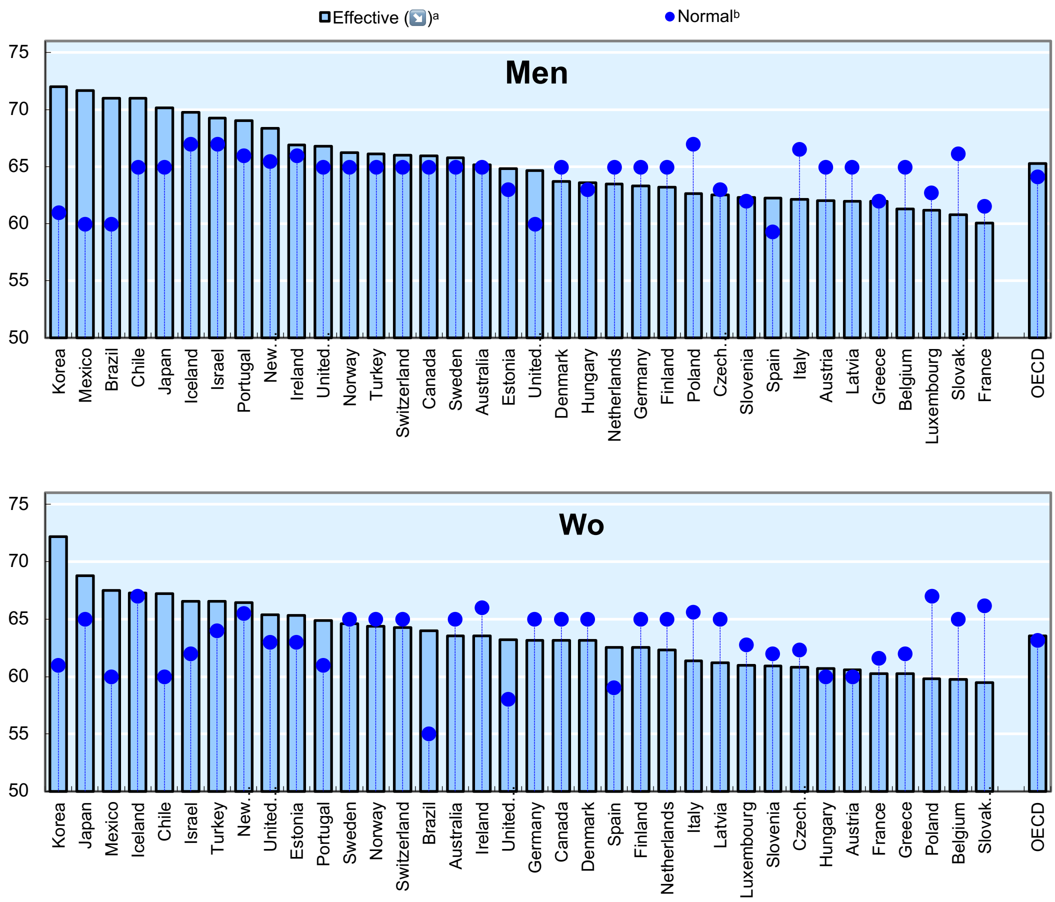


Figure 2.4: Legal retirement age versus effective retirement age in 2011-2016 (OECD, 2017)

Figure 2.4 presents a comparison between the legal retirement age and the effective retirement age in the 2011-2016 period. It can be noted that the aging population and the social benefits after retirement directly influence the decision to stop working. Poland, Belgium, and the Slovak Republic suggest more benefits after retirement, for men and woman respectively, in comparison with Korea, Mexico and Brazil, for instance. Although a new reform project is in the implementation phase in Brazil, the official age for retirement is 60 for men and 55 for woman (the lowest), but the effective age is around 71 and 64 respectively (Bureau, 2018; Munnell, 2011).

Virtually all countries have some kind of pension system, but over the past two decades, there has been an explosion of new tax-financed, non-contributory "social" pensions. Some of the biggest changes in 2014 have been driven by the extension of social pensions, such as in Latin American countries that have dramatically extended coverage reflecting a recent global trend

(HelpAgeInternational, 2018). The rise of social pensions marks a shift in priorities for pension policy.

In our work, we propose elderly collaborative care services that attend the elderly care needs and minimize the social changes. We further these services and related support technologies to the four life settings defined by BRAID Project (Camarinha-Matos et al., 2013a)

- Independent living - how technology can assist in normal daily life activities e.g. tasks at home, mobility, safety, agenda management (memory help), etc.;
- Health and care in life - how technology can assist in health monitoring, disease prevention, and compensation for disabilities;
- Occupation in life - how technology can support the continuation of professional activities along the ageing process; and
- Recreation in life - how technology can facilitate socialization and participation in leisure activities.

2.2 Collaborative Network Discipline

Historically, the use of technology has assisted organizations in many ways of doing business. The pervasive use of open distributed system, as observed with Internet-based solutions, enables efficient distributed businesses, rapid time to market, and cost-effective innovation in a globalized environment (Gartner, 2018). In highly dynamic domains, such as health and personal services, companies are challenged to be able to efficiently interplay with multiple organizations to compose personalized offers without losing competitiveness and quality in their services. Typically, there are three networking levels involving multiple organizations, as shown in Figure 2.5 (Camarinha-Matos & Afsarmanesh, 2008c; Elliott, 2007).

The first level, represents networking and coordinated networking, which involves communication and information exchange for mutual benefit and the act of working together harmoniously. The next level explores cooperation, which involves information exchange and adjustments of activities, combined with sharing of resources for achieving compatible goals, and usually involves labour division among participants. The last level represents collaboration, which involves networking, coordination, cooperation, and mutual engagement of participants to solve a problem.

This implies mutual trust, which takes time, effort, and dedication. The iteration and integration among participants grow as the degree of networking increases, and although the requirement is larger and also more difficult to reconcile, the best results generally happen as there is collaboration (Elliott, 2007).

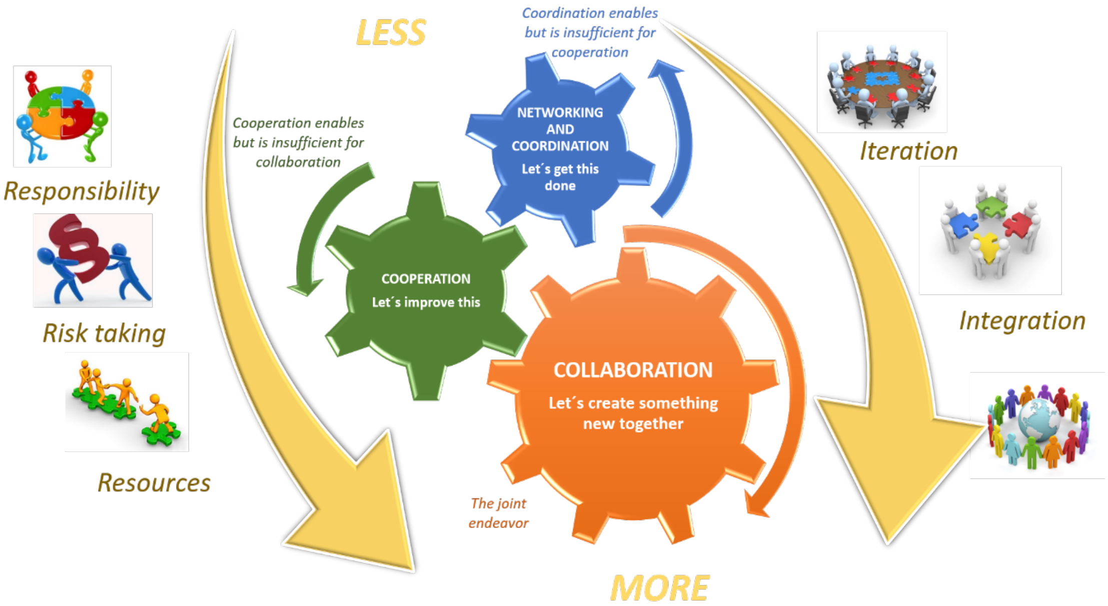


Figure 2.5: Networking Basic Concepts – adapted from (Camarinha-Matos & Afsarmanesh, 2008c; Elliott, 2007)

The use of a collaborative environment offers a number of advantages to the engaged organizations including "survivability in a context of market turbulence, acquisition of a larger apparent dimension, access to new or wider markets and new knowledge, sharing risks and resources, joining of complementary skills, reaching high level of agility, and better achieving common goals" (Bititci et al., 2012; Camarinha-Matos et al., 2010a; Crispim & de Sousa, 2010).

In this context, a collaborative network (CN) is defined as "an alliance constituted of a variety of entities (e.g. organizations and people) that are largely autonomous, geographically distributed, and heterogeneous in terms of their operating environment, culture, social capital and goals, but that collaborate to better achieve common or compatible goals, and whose interactions are supported by a computer network" (Camarinha-Matos & Afsarmanesh, 2008b).

Examples of business areas that have benefited from the adoption of the collaborative networks paradigm include the classical supply chain in automotive industry (Meyr, 2009; Sánchez & Pérez, 2005; Zhu et al., 2007), the agribusiness sector (FORAGRO, 2010; Ojijo et al., 2013; Volpentesta & Ammirato, 2013), the transport sector (Osório et al., 2010), smart grid sector (Camarinha-Matos, 2016; Cao & Zhang, 2011), water management (Hong et al., 2014; Romano & Kapelan, 2014), biodiversity data providers (Fuentes & Fiore, 2014), ICT and aging (Camarinha-Matos et al., 2010b; Plaza et al., 2011), etc. More specifically for the elderly care domain, examples can extend to home safety and care, localization and mobility assistance, health monitoring, rehabilitation and disabilities compensation, caring and intervention on medication or nutrition, learning support system, social and entertainment services, adjusted working spaces, intergenerational relations, assisted living facilities (e.g. with sensors, smart home appliances, and services robotics), senior intelligent villages, etc. (Camarinha-Matos et al., 2015).

In order to guide the collaborative networks applications and modelling, Camarinha-Matos and Afsarmanesh (2008c) proposed a comprehensive modelling framework called ARCON (A Reference Modelling Framework for Collaborative Networks). ARCON intends to support different modelling levels for collaborative networks, ranging from general representations to specify models of CNs. Actually, ARCON represents a modelling framework that addresses the complexity involving the representation of CNs, and thus adequate to model Ambient Assistance Living (AAL) ecosystems (Camarinha-Matos et al., 2015; Osório et al., 2010).

2.2.1 Collaborative Networks Classification

Generally, collaboration requires some organizational structure, assignment to each member of the activities they must perform, identification of roles for participants, and definition of management rules. This led to the emergence of many variants of Collaborative Networks. Figure 2.6 presents a partial taxonomy of these variants.

Most of collaborative networks manifestations are usually business-oriented and present clear organizational structures - Collaborative Network Organizations (CNOs) (Figure 2.6-1). Other more spontaneous collaborative networks can emerge, as a result of people grouping themselves to enhance an overall goal by contributing individually and voluntarily. These CNs are known as Ad-hoc Collaboration forms (Figure 2.6-2). For instance, conducting the search for a missing group in a mountain or in the case of rescue after a hurricane that passed through a city are typical examples of this sort of CN. These two kinds of CNs represent the first level of a CN taxonomy.

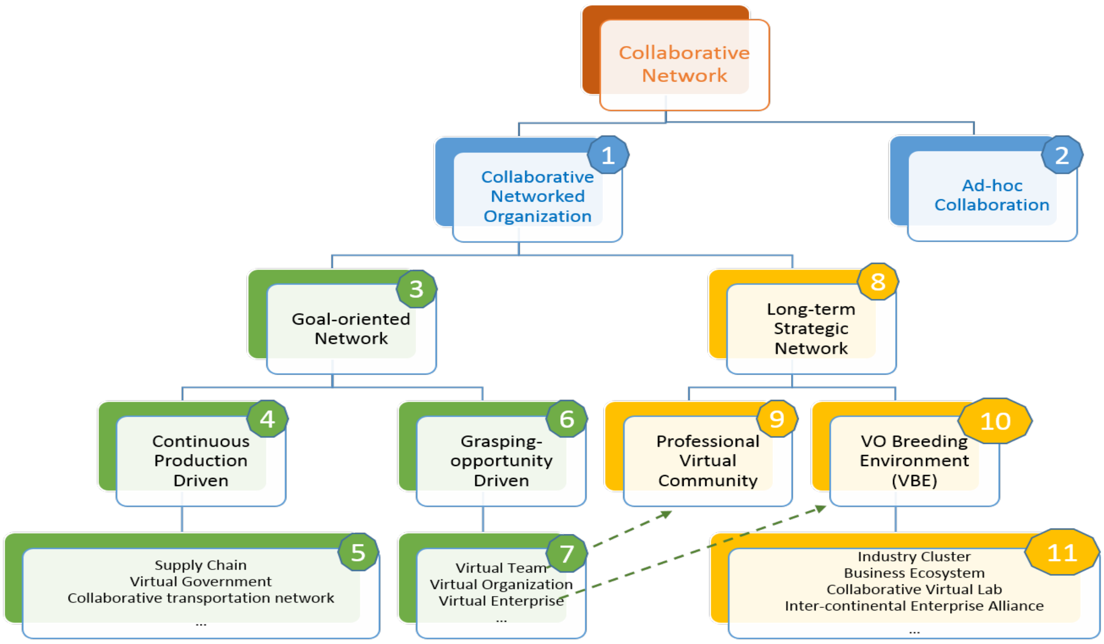


Figure 2.6: Taxonomy of Collaborative Networks, adapted from (Camarinha-Matos & Afsarmanesh, 2005)

Among the CNOs, some networks are goal-oriented (Figure 2.6-3) in which intense collaboration (towards a common goal) is practiced among their partners. This category covers continuous production driven networks (Figure 2.6-4), including those networks that have a long-term duration and remain relatively stable during that duration, with a clear definition of members' roles along the value chain. Supply chain, virtual government, collaborative transportation network are examples of this kind of collaborative networks (Figure 2.6-5). Another kind of goal-oriented network is grasping-opportunity driven (Figure 2.6-6), representing networks that are dynamically formed to answer specific collaboration opportunities and that will dissolve once their mission is accomplished, such as Virtual Enterprise (VE) / Virtual Organization (VO) / Virtual Team (VT) (Figure 2.6-7). This class represents temporary alliances of enterprises/organizations/humans that come together to share skills or core competencies and resources in order to better respond to business opportunities, supported by computer networks (Camarinha-Matos & Afsarmanesh, 2005; Cushman et al., 2000; Kaletas et al., 2005).

The second kind of CNOs is a long-term strategic network (Figure 2.6-8). In this category, it is not collaboration but cooperation that is practiced among its members. This class covers professional virtual communities and virtual organizations breeding environments. A Professional Virtual Community (PVC) (Figure 2.6-9) represents an association which combines the concepts of virtual community and professional community. Virtual communities are defined as social systems of networks of people, who use computer technologies to mediate their relationships. Professional communities provide environments for professionals to share the body of knowledge of their professions, such as similar working cultures, problem perceptions, problem-solving techniques, professional values, and behaviour (Camarinha-Matos & Afsarmanesh, 2008c).

A growing number of virtual communities or social networks specifically for seniors can already be found on the Internet. Some examples are shown in Table 2.1. This sample includes 24 social networks offering services exclusively for seniors, ranging from leisure, dating, and games, to health and sports. Some of these cases go beyond a simple social network and present some characteristics of a virtual professional community, aiming at supporting active aging.

Table 2.1: Examples of Social Networks for Seniors, last access in 2019/04/13

Name	Website
Too Young to Retire	www.2young2retire.com
American Association of Retired Persons	www.aarp.org
Silver Surfers	www.silversurfers.com
60 Plus Association	www.60plus.org
50 Connect	www.50connect.co.uk
Senior Net	www.seniornet.com
Senior	www.wiredseniors.com
Senior.com	www.senior.com
Grow NUPS	www.grownups.co.nz
Senior Friend Finder	www.seniorfriendfinder.com
Senior Match	www.seniormatch.com
50 Years Plus	www.50yearsplus.com
Dating for Seniors	www.datingforseniors.com
Senior Passions	www.seniorpassions.com
Senior Communication	www.seniorcom.jp
Verdurez	www.verdurez.com
Family Ties	www.cloud10.co.jp

Patient Powered	www.patientpowered.us
Buzz 50	www.buzz50.com
eHarmony	www.eharmony.com
Vital Senior	www.vitalsenior.com.br
Portugal Senior	www.portugalsenior.org
Stitch Connection	www.stitch.net/
EAC—Empower Assistance Care	eac-network.org/seniornet/

Advances in Internet and pervasive computing have boosted collaboration possibilities and enabled or induced the emergence of new collaboration forms. However, the rapid formation of a CN to respond to a business opportunity also faces a number of challenges, whereas the two most relevant are: (*i*) dealing with the large heterogeneity (technological infrastructures, business practices, culture, etc.) among the autonomous participants involved in the process, and (*ii*) the necessary time to build trust relationships (Camarinha-Matos et al., 2010a).

One approach to overcome these challenges is to establish "long-term strategic" alliances. In this direction the concept of Virtual Organizations Breeding Environment (VBE) (Figure 2.6-10) has been introduced as an "association of organizations and the related supporting institutions, adhering to a base long-term cooperation agreement, and adopting common operating principles and infrastructures. The main objective of this association is to increase the preparedness of its members towards rapid configuration of temporary alliances for collaboration" (Camarinha-Matos & Afsarmanesh, 2005).

Several aspects must be considered by an organization when deciding to join a strategic network like a VBE. As an illustration, a sample of the aspects that positively impact the adoption of business models based on VBEs is shown in Table 2.2 (Bititci et al., 2012; Camarinha-Matos et al., 2008). The involvement of an organization into a VBE might have two main purposes: improving the member's management capabilities or improving the strategic-level of the business operation (Bititci et al., 2012).

Table 2.2: Motivations to Participate in a Virtual Organizations Breeding Environment (VBE)

Management Capabilities	Strategic Level
• Improve the management of competencies and resources;	• Cope with market turbulence; • Increase chances of survival: agility is opportunity-based VO creation;

• Develop approaches to build trust; • Efficient common ICT infrastructure, mechanisms; • Improve potential for risk-taking; • Support members through necessary re-organization; • Provide learning and training; • Share assets; • Join advertisement campaigns; • Develop core competencies; and • Help to attain clear focus.	• Improve chances to compete with larger companies, lobbying, and market influence; • Facilitate access to loans; • Decrease costs of group insurance; • Improve the negotiation power, prestige, reputation, and reference; • Leverage opportunities to access new markets or product; • Expand geographical coverage; • Increase potential for innovation; and • The economy of scale and achieve diversity.

While participation in a VBE has advantages, as illustrated in Table 2.2, there are also some challenges. For instance, we can point out the fact that VBE partners may have to share resources and internal company information. This information can be used by organizations that do not follow proper ethical principles which may cause losses to the company (Afsarmanesh et al., 2012).

Among the VBEs, we highlight the Business Ecosystem (Figure 2.6-11) sub-class which is inspired on biological ecosystems and is a relevant category of long-term strategic networks. This concept suggests "an economic community supported by a foundation of interacting organizations and individuals—the organisms of the business world. This economic community produces goods and services of value to customers, who themselves are members of the ecosystem" (Moore, 1993).

2.3 Business Service and Business Ecosystem

The concept of "service" has been developed mainly in two areas: computer science and management. For the ICT community, a software or technical service represents a computational action executed in response to a trigger event. On the other hand, from the business perspective, business services add value to a customer (Baldissera & Camarinha-Matos, 2016b; Sanz et al., 2006; Xu & Wang, 2011). According to the same authors, it is logical to separate these two views, being worth noting that business service delivery is performed through business process execution. The activities of a business process can be done automatically (invocation of some software service) or manually (human-executed activities). Nevertheless, the concept of business service itself is not clearly defined, and different authors offer slightly different notions. Table 2.3 provides some definitions for business service.

Table 2.3: Business Service Descriptions

Business Services	Reference
"A change in the condition of a person, or a good belonging to some economic entity, brought about as the result of the activity of some other economic entity, with the approval of the first person or economic entity".	(Hill, 1977)
"Such a kind of specialized services and business operations mainly concerned with providing professional and specialized support for the business processes of other organizations, i.e., the clients".	(Bettencourt et al., 2005)
"A business activity, part of organization's business model, resulting in intangible outcomes or benefits".	(Baida et al., 2004)
"A specific set of actions that are performed by an organization".	(Sanz et al., 2006)
"Are present at a time T and location L if, at time T, the agent is explicitly committed to guaranteeing the execution of some type of action at location L, on the occurrence of a certain triggering event, in the interest of another agent and upon prior agreement, in a certain way".	(Ferrario & Guarino, 2009)
"Traditional services that feature higher inclusions of ICT and human capital adopt new techniques, new innovative business models, and new resource configurations patterns, thereby producing more added-value".	(Xu & Wang, 2011)
(In the elderly care domain) "Are equivalent to what is usually called care and assistance service: services provided to the end users which involve a number of software services and human intervention".	(Camarinha-Matos et al., 2013a)

From the definitions presented in Table 2.3, it can be inferred that care and assistance services for elderly can be considered a kind of business service. The notion of business process corresponds to the management of services execution, involving both software services and manual services.

Figure 2.7 gives a structure to the notion of Care and Assistance Service in the Elderly Care Domain. Software services fundamentally represent software applications that define part of a system which can be "consumed" distinctly by numerous objects (Kohlborn et al., 2009). Thus, software services execute elements that perform business processes activities. Manual services correspond to services provided to the customers which involve some human interventions (Wang & An, 2010). Hence software services and manual services support the business process execution, materializing the notion of business service delivered to the customers (Kohlborn et al., 2009).

Currently, most initiatives on elderly care services have been focused on isolated and techno-centric services development, considering only a single service. However, in the elderly care domain, personalized services should cover the specific needs of each user, respecting the elderly individuality, and the evolution of limitations that come as the person and life environment change (Jula et al., 2014; O'Grady et al., 2010; Sanz et al., 2006). In this context, it is natural the need of multiple services and multiple providers that attend specific needs of an individual.

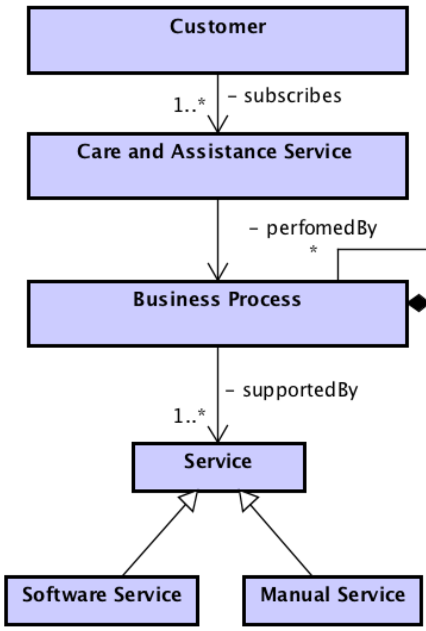


Figure 2.7 : Care and Assistance Service in the Elderly Care Domain

Complementary to the notion of a business service, a business ecosystem (and thus a care ecosystem as well) can be identified as a "particular case of a VBE, which tries to preserve local specificities, tradition, culture, and frequently benefit from local government incentives, involving a complex interplay of collaboration and competition around producers, consumers, regulators, and support entities" (Camarinha-Matos et al., 2010a; Camarinha-Matos et al., 2012a).

An example of business ecosystem is given by the term Digital Business Ecosystem (Kearney, 2013), which is also inspired on biological ecosystem, but with a stronger emphasis on the technological support perspective. On the other hand, based on advances in the discipline of Collaborative Networks, and current demanding market challenges (better services and prices, market survival, increase of competitors, etc.), the term Collaborative Business Ecosystem (CBE) was introduced to emphasize the "collaborative environment" perspective

(Baldissera & Camarinha-Matos, 2016b; Camarinha-Matos, 2013; Graça & Camarinha-Matos, 2015). A CBE supports organizations which must collaborate to overcome their weaknesses and strengthen their expertise and skills, to offer better integrated (composite) services and acquire competitive advantage with the focus on customer satisfaction.

A CBE is thus supposed to provide a variety of software services and manual services that can be combined to fulfill the needs of each customer. This requires proper management of business services composition and integration, as explained in the next Section. By adopting this approach, we can say that care and assistance services for elderly should (likely) result from the collaboration among various entities, possibly including governmental and non-governmental organizations, individual or cooperative professionals, family, friends, caregivers, etc., which in consequence calls for a supporting collaboration environment.

2.4 Care Service Composition, Personalization and Evolution

Building business solutions typically requires combining multiple available business services. A service composition is an aggregation of services (atomic or integrated) collectively composed to deliver a particular service pack or business process (Kapitsaki et al., 2007). These composite (or integrated) services can be in turn recursively composed with other services into higher level solutions, (and so on), constituting an essential part of service provision. The novel (composite) service is adding value that was not existent in the atomic services.

In the CBE context, a single provider probably might not be able to cover all care needs of a customer, since a service provider typically has its area of service application and a customer typically may have needs (required services) of various areas. As such, service providers may get together in alliances aiming at the creation of composite services which can better meet the entire customer's care needs.

A composite service may thus involve several service providers, requiring various devices and a support infrastructure, depend on another service or resource, involve people and frequent information exchange, etc. (Baldissera et al., 2017a). Therefore, managing all these elements and relationships with efficiency is indeed a significant challenge.

The notion of service personalization means that a service is tailored to fit each individual (Evenson & Dubberly, 2010; Hong et al., 2009; Kwortnik Jr et al., 2009; LeadingAge, 2017; Lee, 2007). For several authors, e.g., (Kwortnik Jr et al., 2009; Lee, 2007; Manoharan et al., 2015), personalizing a service covers an agreement between customers and providers (and possibly other involved stakeholders) through which they share information to be organized intelligently and adaptively.

The effective establishment of a CBE requires, in fact, a proper understanding of the customers' profile in order to ensure that offered services are both competitive in market terms and relevant to the individuals. Some customers may require distinct types of care services to satisfy their particular needs, which lead to the notion of personalized services.

If the elderly and family are satisfied with the provided service, they feel like an exclusive customer and are inclined to keep loyalty towards the service provider (Lee, 2007). Collecting feedback information in this context can help service providers to deliver better-personalized services. Direct communication with customer representatives remains the most preferred channel for consumers and small companies with few customers. In this scenario, it is "easy" to personalize customers services (Manoharan et al., 2015). However, businesses (e.g., care service providers) with many customers need to seek multiple information sources to achieve personalization, using both human interventions and automatized mechanisms. These feedback acquisition transactions can be efficiently handled through ICT strategies like Internet of Things (IoT) devices and tele assistance (Alwan et al., 2007; Camarinha-Matos et al., 2015).

In the elderly care domain, it is primordial to understand the customer, her/his limitations, and longings, as well as the elderly living environment and associated stakeholders (Baldissera et al., 2017b). As a consequence, a personalized service package is likely to be provided by some providers working together, acting as a virtual organization.

<u>Service evolution</u> is the process of maintaining and evolving existing care services to cater for new requirements and technological changes (Wang et al., 2014). The CBE needs to constantly monitor the context and, for each new context change, to analyze the situation, plan the service evolution, and implement the evolution to fit that context.

An evolutionary ambient assisted living system is suggested by O'Grady et al. (2010) following this vision, but their focus is on a techno-centric evolution and adaptability of the system, and ignore the service providers and stakeholders. More recently, new developments appear to address user-stakeholders-centric services, combined with ICT, to offer services nondependent of a place and time (Chiarini et al., 2013; Mukhopadhyay & Suryadevara, 2014; Xu & Wang, 2011).

Under this perspective, the notion of evolutionary service (Camarinha-Matos et al., 2015; Hong et al., 2009; LeadingAge, 2017; Millar et al., 2016; Xu & Wang, 2011) means that the provided service adapts to the customer's needs, environment and any changes that affect the customer's life context, as well as CBE demands, new regulations, and technological requirements.

In the literature, researchers present partial solutions for service composition (Afsarmanesh et al., 2012; Jula et al., 2014; Kapitsaki et al., 2007), service personalization (Baida et al., 2004; Baldissera et al., 2017b; Brown et al., 2002; Camarinha-Matos et al., 2015) and service evolution (Millar et al., 2016; O'Grady et al., 2010; Wang et al., 2014), mostly considering single service providers and comparison between isolated services (not combined with the service provider). In (Silva, 2018), service selection and ranking in cross-organizational business processes collaboration is considered. In this work, different parts of a business process are performed by different organizations (services providers in our approach). The focus of (Silva, 2018) is based on business strategies in the industrial sector. Our proposal is similar but emphasizes a user-centric view of elderly care (elderly profile and requirements) and integrates providers of different nature (regulators, support entities, and service providers) and categories (public, private, non-governmental, and mixed).

2.5 Potential Technologies for Aging Support

As previously described, population aging can cause many societal changes. These changes have implications in many areas of policy and practice, including the area of ICT systems. These systems are becoming more and more part of daily life, also presenting valuable opportunities for supporting and engaging older people. ICT and assistive technologies, in general, have already become an integral part of the life of many people, including the elderly.

In addition to its importance in improving the management and delivery of care and assistance services, ICT can play a key role on improving the life quality of older people, enabling better integration in society, improving family and community relationships, and consequently well-aging (Carneiro et al., 2012; Pfannstiel & Rasche, 2019).

The idea that the senior population is still unwilling to use computers is deprecated, and more and more elders use technology in their daily life.

PewResearchCenter (2019) points that 80% of adults and almost 60% over age 65 use the Internet daily. However, when considering elderly over 77 years this percentage decreases to a third.

Nevertheless, elderly people still have to face several challenges in order to be included in an increasingly technological society. Seniors´ characteristics and needs are very different from the mainstream audience of new technologies and the number of systems that consider these differences is scarce to non-existent (Cresci et al., 2010). In fact, some constraints can be observed in their interaction with computer systems, which are yet to be fully prepared to accommodate seniors' capabilities and limitations.

Many computer tasks are characterized by having high cognitive demands (Czaja & Lee, 2009; Ramprasad et al., 2019) and this fact puts seniors at a disadvantage, which requires both researchers and professionals to design suitable products and services for this audience, providing them the benefits that technology can offer. This situation brings the challenge of approximating aging and ICT.

As such, it is necessary to use a more creative approach where providers become more willing to draw from professionals and elderly people as they develop, test, refine, and market their products and services (Opalinski, 2001; Ramprasad et al., 2019; Scialfa & Fernie, 2006). In doing so, the creation of systems and services that address the specific range of needs and interests could more easily appeal to seniors, decreasing their distance towards technology (Hanson, 2010).

Figure 2.8 presents a map of care and assistance service dimensions (LeadingAge, 2017; Marcos-Pablos & García-Peñalvo, 2019) which can guide a personalization and evolution of services provision by a collaborative business ecosystem.

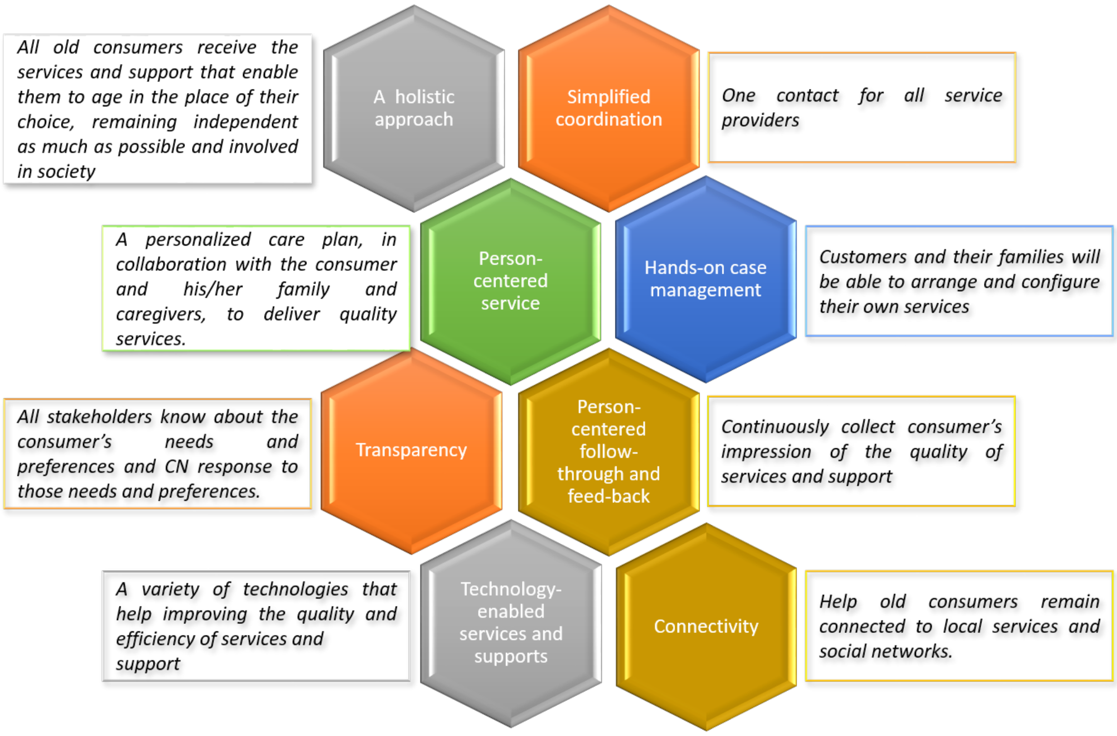


Figure 2.8: Future for care and assistance services. Adapted from (LeadingAge, 2017)

Direct communication with customer representatives remains the most preferred channel by consumers and for small companies with few customers. In this scenario, it is easy to personalize customers services (Manoharan et al., 2015). However, businesses (e.g. care providers) with many customers need to seek multiple information sources to achieve personalization, using both human interventions and automatized services. These feedback acquisition transactions can be efficiently handled through ICT strategies (Alwan et al., 2007; Camarinha-Matos et al., 2015; Marcos-Pablos & García-Peñalvo, 2019).

Additionally, recent progress on Internet of Things (IoT), sensors and other intelligent devices, including holographic glasses (e.g. Microsoft Hollolens), visual capture of the person pulse and weight (e.g. Xbox Kinect motion capture technology) , home automation (e.g. refrigerator that controls the products validity date), and robotized systems (e.g. personal trainer and accompanying robot), creates the opportunity for better offering of evolutionary services. In particular, context aware technologies can have a considerable impact on the provision of personalized and evolutionary services (Chiarini et al., 2013; Marcos-Pablos & García-Peñalvo, 2019; O'Grady et al., 2010).

2.5.1 Context Aware Technologies

A context represents any information that can be used to characterize the situation of an entity (Abowd et al., 1999; Dey et al., 2001; Yau & Karim, 2004). An "*entity*" can be people, place, or object that is considered relevant to the interaction between a customer and an application, including location, time, activities, and the preferences of each entity. The concept of context can be described independently of the actions done, but some authors (e.g. (Dourish, 2001; Winograd, 2001)) understand that something is contextualized because of the way it is used in interpretation. On the other hand, Sato (2003) proposes to represent a context through "*a pattern of behaviour or relations among variables that are outside of the subjects of design manipulation and potentially affect user behaviour and system performance*".

Context awareness is thus about capturing a broad range of contextual attributes (such as the user's current positions, activities, and surrounding environments) to better understand what the customer is trying to accomplish, and what services the costumer might be interested in (Lee, 2007). For Costa et al. (2004) context-awareness seeks to exploit human-computer interactions by providing computing devices with knowledge of the users' environment, i.e., with context. Context awareness computing is a recent and promising development (Scoble & Israel, 2014).

Currently, many technologies contribute to the development of context-aware solutions. They have enlarged the possibilities of producing cutting-edge products dedicated to distinct segments of our society. In a broad sense, Scoble and Israel (2014) and (Marcos-Pablos & García-Peñalvo, 2019) highlight five forces that have shaped and cooperated with the advances on context-aware technologies. We briefly describe these forces as follows:

- *Mobile:* CISCO (2014) shows that mobile devices outnumbered humans in 2012. Wearable computing is booming, with some estimates that the unit sales of wearables will rise from 15 million in 2013 to 70 million by 2017 (Moar, 2014), data communication costs are dropping (Moar, 2014), and app downloads have increased sharply. It is estimated that apps were downloaded 85 billion times in 2019(Gartner, 2018). In another direction, it is anticipated that implant wireless identifiable devices could be used to store health records that could save a patient's life in emergency situations or biodegradable chips could be introduced into the body and used for guided action.

- *Social Media:* The investment in social networks was expected to increase by 300% over the period 2015-2018, a growth fuelled by the desire of individual and organizations to distribute timely content with their community (Rymer et al., 2015). Almost 1.5 billion people are on social networks, and businesses are using them to connect with customers, "humanize" themselves, and learn. Specific groups use specific social networks, like the elderly social networks described in Table 2.1.
- *Data:* The size of Internet connected data sources is expanding at an exponential rate – leading to the idea of big data. Big companies estimate that 90 percent of the world´s data was created in the last two years (Gartner, 2018) The demand for analytics, providing a level of quantitative analysis on key data sets is impacting a business and more importantly, where informed decisions can be made is increasing. Similarly, the analysis of large amounts of data about the elderly context, might allow the development of new specific services related to care and assistance (Marcos-Pablos & García-Peñalvo, 2019).
- *Sensors*: Technological sensors can emulate (and extend) three of the five human senses: sight, touch, and hearing. For instance, sensors for temperature or humidity provide the necessary data to automatically adjust the comfort level and to optimize the use of energy for heating or cooling or enabling smart metering for measuring energy consumption and transmitting this information to the energy provider electronically (Marcos-Pablos & García-Peñalvo, 2019).
- *Location-based services*: Our location is one of the most important parts of our context because it can impact some key characteristics of customer interaction, such as the scope of the service, and its duration and frequency (Fano & Gershman, 2002; Raab et al., 2018).

These trends can directly influence decisions through a context analysis and supported by a wide range of sensors, smart devices and new services (Majumder et al., 2017). These devices in a communicating–actuating collaborative network create the IoT, where sensors and actuators blend seamlessly with the environment around us.

The complexity and diversity of available services has grown, being important to establish the basis for assessment of services quality. Another concern is to cover new services to facilitate elderly interaction and service delivery nondependent of place and time (Camarinha-Matos et al., 2012a; Camarinha-Matos et al., 2015; Marcos-Pablos & García-Peñalvo, 2019; O'Grady et al., 2010).

Supported by the adaptation of a variety of enabling wireless technologies, e. g. RFID tags and embedded sensors, Internet of Things (IoT) grows and is considered the next revolutionary technology in transforming the Internet into a fully integrated Future Internet (Gartner, 2018; Gubbi et al., 2013) IoT devices can help in the identification and analysis of the context and provide relevant inputs for evolving care and assistance services.

2.5.2 Internet of Things

Typically the term Internet of Things (IoT) refers to *"the interconnection of uniquely identifiable embedded computing devices within existing Internet infrastructure"* (Choi, 2014). The term is closely related to smart objects that interact and communicate with other machines, physical environments, and infrastructures.

IoT is an integrated part of "*Future Internet and could be defined as a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network*" (Sundmaeker et al., 2010). A "thing" in this context could be defined as a real/physical or digital/virtual entity that exists and moves in space and time and is capable of being identified. Things are commonly identified either by assigned identification numbers, names and/or location addresses.

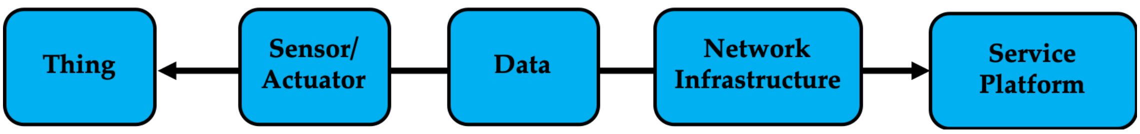


Figure 2.9: Elements that Comprise the IoT, adapted from (Sundmaeker et al., 2010)

Figure 2.9 lists the main elements that comprise the IoT:

- Network infrastructure: "*A dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols […]";*
- Things, sensors, and actuators: "*[…] where physical and virtual 'things' […]";*
- Data: "*[…] have identities and physical attributes (sensors and actuators) and virtual personalities […]";*
- Service platform: "*[…] and use intelligent interfaces and are seamlessly integrated into the information network.*"

The IoT vision of pervasively connecting several "things" lets systems being able to interact with the environment around us and receive information about it, which was not previously available. Another related concept is the cyber-physical systems (CPS). According to (Camarinha-Matos et al., 2013c), "*Cyber Physical Systems include not only things connected to the Internet, but also other physical systems with embedded computational power*". While the traditional notion of Cyber Physical System (CPS), known as the local network of a set of things (e. g., wireless sensor networks), can only extract "regional" information containing specific content from the things, IoT can provide a larger scale, comprehensive, and historical information by allowing collaboration among different intranets of things. Furthermore, IoT enables the creation and composition of new services and applications, offering to individual users a new ecosystem where different networks of things can collaborate (Ortiz et al., 2014).

Mukhopadhyay and Suryadevara (2014) anticipated some years ago that IoT is the next revolution in computing. While smartphones and the mobile Internet saw the advent of mobile applications for the costumer, current trends point to the pervasive integration of semiconductors, mobile communication, and big data/analytics propelling the IoT into the economy. Also, the key drivers of IoT include the price reduction and standardization of key hardware and software components, and the level of integration with Big Data/Analytics.

Figure 2.10 shows that IoT was on top of the hype cycle in 2018 and expected to reach its maturity in about four to nine years. This trend is likely to drive potential changes in business models and/or significant cost savings.

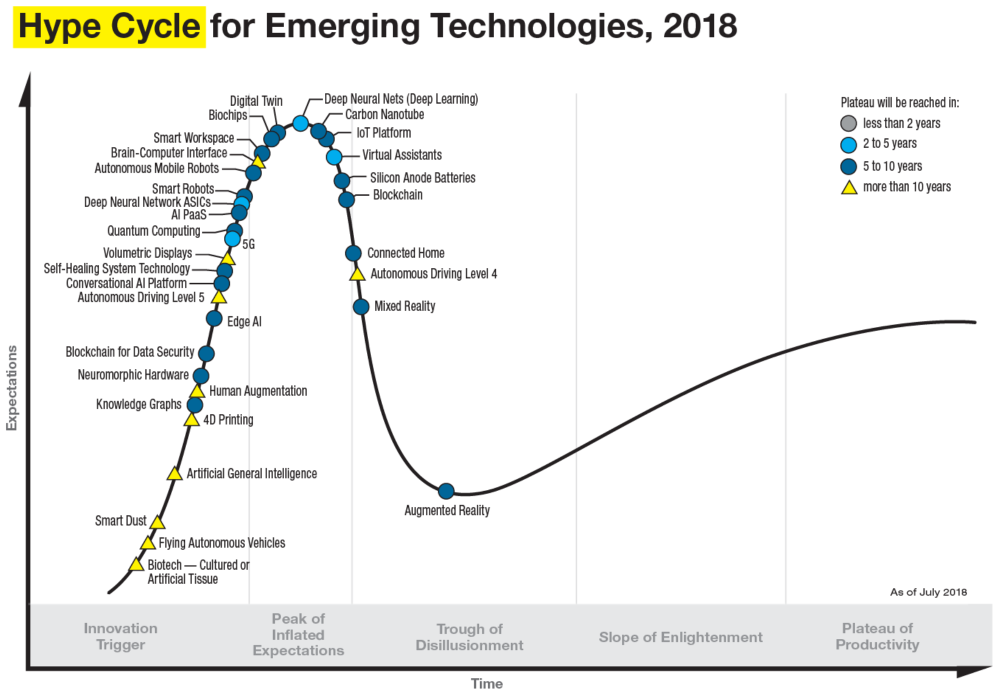


Figure 2.10: Hype Cycle for emerging technologies in 2018 (Gartner, 2018)

Also motivated by implementation of emerging IoT technology,

Figure 2.11 presents the expected growth trend of computational devices over time. This trend points to the importance of being familiarized with these technologies and their potential and limitations, so that they can be exploited to develop smart and innovative applications (Majumder et al., 2017).

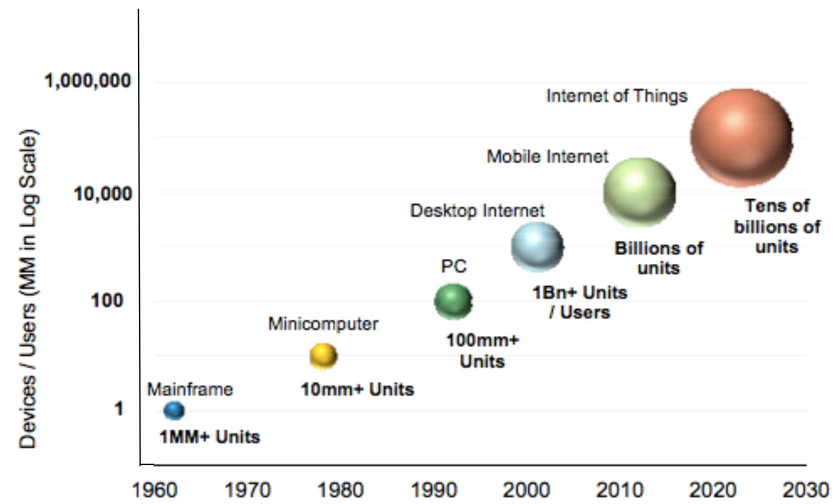


Figure 2.11: Computing Growth Drivers Over Time – 1960 -2030 (Majumder et al., 2017)

This technology is becoming present everywhere at the same time, leading to the term "ubiquitous computing" which enables businesses to redefine the key aspects of their customer relationships. Businesses can continuously become aware of their customer's needs and provide more natural and powerful means of access to their services. By using sensors and location resources, companies can become more responsive to their customers (Fano & Gershman, 2002; Perez et al., 2018).

In this way it is expectable that IoT can be a strong ally in supporting evolutionary collaborative business services for elderly care (Baldissera & Camarinha-Matos, 2018b; Perez et al., 2018). The next section shows possible scenarios and applications for elderly care services that can strongly use IoT technologies .

2.6 Research Work in the Area of Technologies and Aging

2.6.1 Projects on ICT and Aging

Recent progress on technological devices creates the opportunity for new classes of services for elderly people (Baldissera & Camarinha-Matos, 2018a; Camarinha-Matos et al., 2013b; Perez et al., 2018). This trend is reflected in a large number of research initiatives on Information and Communication Technologies (ICT) and aging during the last decade. This is clearly illustrated by an analysis of 230 projects started since 2001 as part of ICT and Aging agenda of European framework programs. From the 230 projects, 178 consider a simple provider (a unique entity providing the service) and 52 consider collaborative providers (various entities together provide the service – integrated service or service package) in the four life settings defined by the BRAID[2] - Bridging Research in Ageing and ICT Development - roadmap project (Camarinha-Matos et al., 2013a): Independent living, health and care, occupation in life, and recreation in life.

[2] http://www.braidproject.eu/

Earlier projects developed from 2001 to 2008 had focused on services using single providers. The concern was to meet the maximum service level by the same provider. The AMIGO[3] project – Ambient Intelligence for the Networked Home Environment [2004-2008] was one of the first projects addressing collaborative providers with integrated services. Although AMIGO was not specifically for aging solutions, the project suggested solutions for independent living that were promising and followed by other projects. Since 2009, projects aimed at single providers continue but a large project aimed at elderly health, the EMOTIONAAL[4] project [2009-2012], effectively focused on services delivered through various providers in the context of Europe.

The aim of EMOTIONAAL is to develop an integrated healthcare-concept for elderly people in rural areas in Europe. In this project an integrated solution for the elderly was developed based on seamless inclusion of social services and new technologies, named "The Emotional Village". The project includes intense support for self-care and prevention and assistance to carry out daily activities, health and activity monitoring, enhancing safety, and security.

Since 2009 to 2017, other projects have been funded, which focus on collaborative providers. Of these projects, the main relevant projects that deliver atomics services (a single business service) were:

- LLM - Long Lasting Memories: a unified solution for cognitive and physical health and autonomous loving for senior citizens [2009-2012];
- OsteoLink - T-Break [2010-2012];
- AWARE [2010-2013];
- Go-MyLife - Going on line: my social Life [2010-2013];
- Join-IN - Join In Senior Citizens Overcoming Barriers by Joining Fun Activities [2010-2013];
- MyLIFE [2011-2013];
- HOST [2011-2014];

[3] ftp://ftp.cordis.europa.eu/pub/ist/docs/directorate_d/st-ds/amigo-project-story_en.pdf

[4] http://www.aal-europe.eu/projects/emotionaal/

- SAAPHO - Self-serve, independence and dignity enhancement of seniors through innovative ICT-based solutions [2011-2014];
- CARE@HOME: continuous, automatic and remote monitoring [2011-2014];
- LILY [2011-2014];
- Carer+ - Ageing in the community and at home: developing digital competences of care workers to improve the quality of life of older people [2012-2015];
- InclusionSociety- improving usability of the municipal health services and opening up access to the self- serve society [2012-2015];
- HELASCOL - Helping elders to live an active and socially connected life by involving them in the digital society [2012-2015];
- MEDiATE [2013-2015];
- eWALL – Ewall for active long living [2013-2016];
- CarerSuppport [2014-2017];
- ANIMATE - intergenerAtioNal communIty for coMpAny knowledge TransfEr [2014-2017];
- GIVE&TAKE - Designing a reciprocal exchange service for a good and engaged senior life [2014-2017];
- Elders-UP! - Adaptive System for Enabling the Elderly Collaborative Knowledge Transference to Small Companies [2014-2017];
- SpONSOR - knowledge and competence exchange SOlutioN for Supporting occupation in the life of OldeR adults [2014-2017];
- ActGo-Gate - Active Retiree and Golden Workers Gate [2014-2017].

And the projects that developed integrated services (the kind of business which consists of several individual business service/atomic services combination that can turn into a new service) were:

- ePal - Extending Professional Active Life [2008-2010];

- SOCIABLE Project – Motivating platform for elderly networking, mental reinforcement and social interaction [2009-2012];
- universALL Project – Universal open platform and reference specification for ambient assisted living [2010-2014];
- inCASA Project – Integrated network for completely assisted senior citizen´s autonomy [2010-2014];
- AAL4ALL- Ambient Assisted Living for All [2011-2015];
- ACCOMPANY Project – Acceptable robotics companions for ageing years [2011-2014];
- Dem@Care Project – Dementia ambient care: multi-sensing monitoring for intelligent remote management and decision support [2011-2015];
- PERSSILAA Project – Personalized ICT supported service for independent living and active ageing [2012-2015];
- GIRAFFPLUS Project – Combining social interaction and long-term monitoring for promoting independent living [2012-2015];
- T&Tnet – Travel & Transport solutions through emotional-social NETworking [2012-2015];
- SILVER Project – Supporting independent living for the elderly through robotics [2012-2016];
- Care4Balance – Care for balancing informal care delivery through on-demand and multi-stakeholder service design [2013-2016];
- ROBOT-ERA Project – Implementation and integration of integration of advanced robotics systems and intelligent environments in real scenarios for the ageing population [2013-2015];
- Stop + Go Project– Sustainable technology for older people – get organized [2014-2017];
- INCA Project – Inclusive introduction of integrated care, [2014-2016];

- Beyond silos Project – Learning from integrated eCare practice and promoting deployment in European regions [2014-2017];
- CAREWELL Project - Multi-level integration for patients with complex needs [2014-2017];
- IN LIFE Project – Independent living support functions for the elderly [2015-2018];
- GROWMEUP Project [2015-2018];
- I-SUPPORT Project – ICT supported bath robots [2015-2018];
- MARIO Project – Managing active and healthy ageing with use of caring service robots [2015-2018];
- RADIO Project – Robots in assisted living environments: unobtrusive efficient, reliable and modular solutions for independent ageing [2015-2018];
- ENRICHME - Enabling Robot and assisted living environment for Independent Care and Health Monitoring of the Elderly [2015-2018];
- City4Age - Elderly-friendly City services for active and healthy ageing [2015-2018];
- ONALABS - Non-invasive smart wearable solution for continuous monitoring of physiological parameters and biomarkers for chronic patients with cardiac and respiratory diseases from the neonate to the elderly [2018].

The most relevant analyzed projects for the current research that are still in progress (or ending) are:

- Eu-CaRE Project – a European study on effectiveness and sustainability of current Cardiac Rehabilitation Programs in the Elderly [2015-2019];
- SELFIE 2020 - Sustainable intEgrated care modeLs for multi-morbidity: delivery, FInancing and performance [2015-2019];
- my-AHA - My Active and Healthy Aging [2016-2019];

- PICASO - Technology solutions for a personal and coordinated care [2016-2019];
- REACH2020 [2016-2020];
- SENSE-Cog - Ears, Eyes and Mind: The 'SENSE-Cog Project' to improve mental well-being for elderly Europeans with sensory impairment [2016-2020];
- HOLOBALANCE - HOLOgrams for personalized virtual coaching and motivation in an ageing population with BALANCE disorders [2017-2020];
- EMPATHIC - Empathic, Expressive, Advanced Virtual Coach to Improve Independent Healthy-Life-Years of the Elderly [2017-2020];
- vCare – Virtual coaching activities for rehabilitation in elderly [2017-2021];
- MARSI - Disruptive technologies for effectively rehabilitating chronic ambulatory disability [2018-2020];
- CO-ADAPT: Adaptive Environments and Conversational Agent Based approaches for Healthy Ageing and Work Ability [2018-2022];
- Chome4Life - Certified smart and integrated living environments for ageing well [2018-2020];
- RayVS1A unique radar sensor system to monitor movement and vital signs for elderly people in care homes [2019-2020];
- BIONIC - Personalized Body Sensor Networks with Built-In Intelligence for Real-Time Risk Assessment and Coaching of Ageing workers, in all types of working and living environments [2019-2021];
- AgeingatWork – Smart, Personalized and Adaptive ICT Solutions for Active, Healthy and Productive Ageing with enhanced Workability [2019-2021];
- DIH-HERO - Digital Innovation Hubs in Healthcare Robotics [2019-2022].

The main focus of these last projects is on independent living and healthy and care. This analysis points to a potential market expansion, especially in the areas of occupation in life and recreation in life.

2.6.2 Scenarios and Applications for Elderly Care

There are many possible applications based on ICT and IoT devices to assist people in their aging process. For instance, acquiring information on elderly routines and raising alerts or sending notifications when detecting abnormal situations. Based on the trends identified in the literature survey, a number of illustrative scenarios could be identified as summarized in Table 2.4 that shows some possible scenarios within the four life settings adopted in this work.

Table 2.4: Example Scenarios

ICT Solutions (examples)	Use Case
Independent Living	
Home safety and care	Monitoring system with cameras giving access to the family of the person who lives alone in the house and has age-related restrictions. Several sensors are also installed, and unexpected behaviour warnings are given to the relatives and persons authorized to identify the state, through the cameras or video conference devices installed in place.
Localization/positioning assistance	A mobile phone that helps plot routes for walks through the neighborhood, smartly guides the senior on pedestrian walkways, provides indications of preferred locations nearby, based on geo-positioning. The whole trajectory is saved and can be accessed by authorized persons and family who can provide tips and intervene at any time.
Mobility and transportation	Using low-cost wearable sensors, which are used to monitor seniors' wellbeing and track their localization. When necessary, these sensors interact with their smart phone, to send relevant information to a care center. The GPS service running on their phone helps seniors

	to plan the trip. It displays their location and indications to move to the intermediate locations of the itinerary, and to get on the public transports.
Health and Care in Life	
Health monitoring	Measurement and monitoring methods of vital functions (temperature, blood pressure, heart rate, cholesterol levels, blood glucose). Whenever there is a change that compromises the senior's health a beep alerts the patient and a warning is also issued to the provider of medical services to take appropriate action.
Rehabilitation and disabilities compensation	A smart wheelchair with robotic manipulators, which can be used to manipulate common household objects and sonar technology to detect obstacles and modify user´s driving commands to ensure that the platform does not collide with any obstacle.
Caring and intervention	An intelligent system can act as a knowledge source, a personal decision-support system, a health and fitness coach, a personal dietician, and much more, giving instantaneous feedback to the user, raising an alarm or informing professional or informal care givers when needed. This also includes the possibility of actions related to behaviour management by giving relevant education information and checking adherence to treatment programs (medication or exercise). This is similar to a virtual nurse.
Recreation in Life	
Socialization	A platform for organizing events in the neighborhood. This platform is organizing tasks and their division as well as establishing contact with everyone involved receiving alerts of ongoing activities, etc.
Learning	A remote learning support system which corresponds to services for remote access to libraries, painting, and general internet. Also, a remote teaching/consulting for skills sharing.

Entertainment	Installed motion sensors, cameras and movement sensitive screens at home and at club games allow seniors with limited displacement capabilities to actively participate in the activities they enjoy most.
Occupation in Life	
Adjusted working space	Computer systems specific for a particular senior staff member who no longer sees well and has an advanced arthritis. The employee performs computer login through biometric identification and the keyboard automatically writes on computer through voice command. The senior reads the information on enlarged screen.
Keeping links with former employers	Construction of an informal environment where former employers relate to the current activities of the company. Seniors exchange experiences on ongoing projects, help to develop strategies and participate in informal meetings through video conferencing tools and ICT.
Inter-generational relations	Senior professional experts who want to help young people in the process of getting jobs, through the construction of their curriculum, the simulation of job interviews, and real situations of professional day-to-day. All through a virtual network collaboration.

Figure 2.12 shows a collection of application example as suggested by BRAID roadmap (Camarinha-Matos et al., 2013a; Camarinha-Matos et al., 2015), in which ICT can support the various life settings.

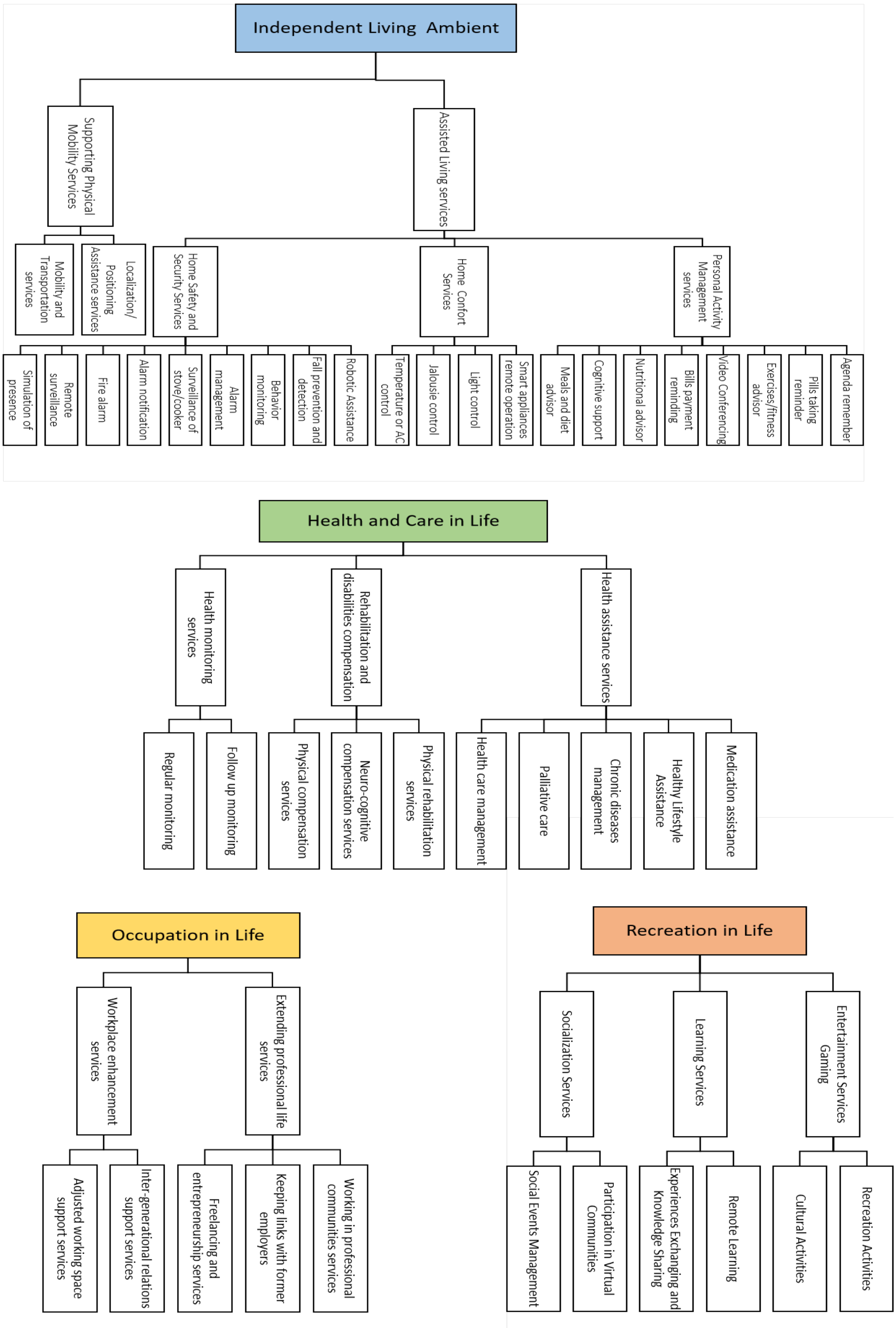


Figure 2.12: Examples of Applications for Elderly Care

2.7 Summary

In the context of aging and well-being, a collaborative Elderly Care Ecosystem has the potential to provide an environment where personalized services might increase customer satisfaction, and give service providers access to new opportunities, share costs and risks, and strengthen their business. In this context, Collaborative Networks are the pillar that fosters collaboration among diverse stakeholders including service providers. However, to accomplish these objectives, rating and composition of care services should respect individual necessities, since care needs can be supported in distinct ways by different providers. In this chapter, we presented the fundamental concerns necessary for the development of our research work. In particular, we presented a literature review about the aging process, the collaborative networks discipline, and research work in the area of technologies and aging. We finalize this chapter by summarizing the capabilities of three main research fields (see Figure 2.13): collaborative networks, collaborative business ecosystems for elderly care, and collaborative service providers.

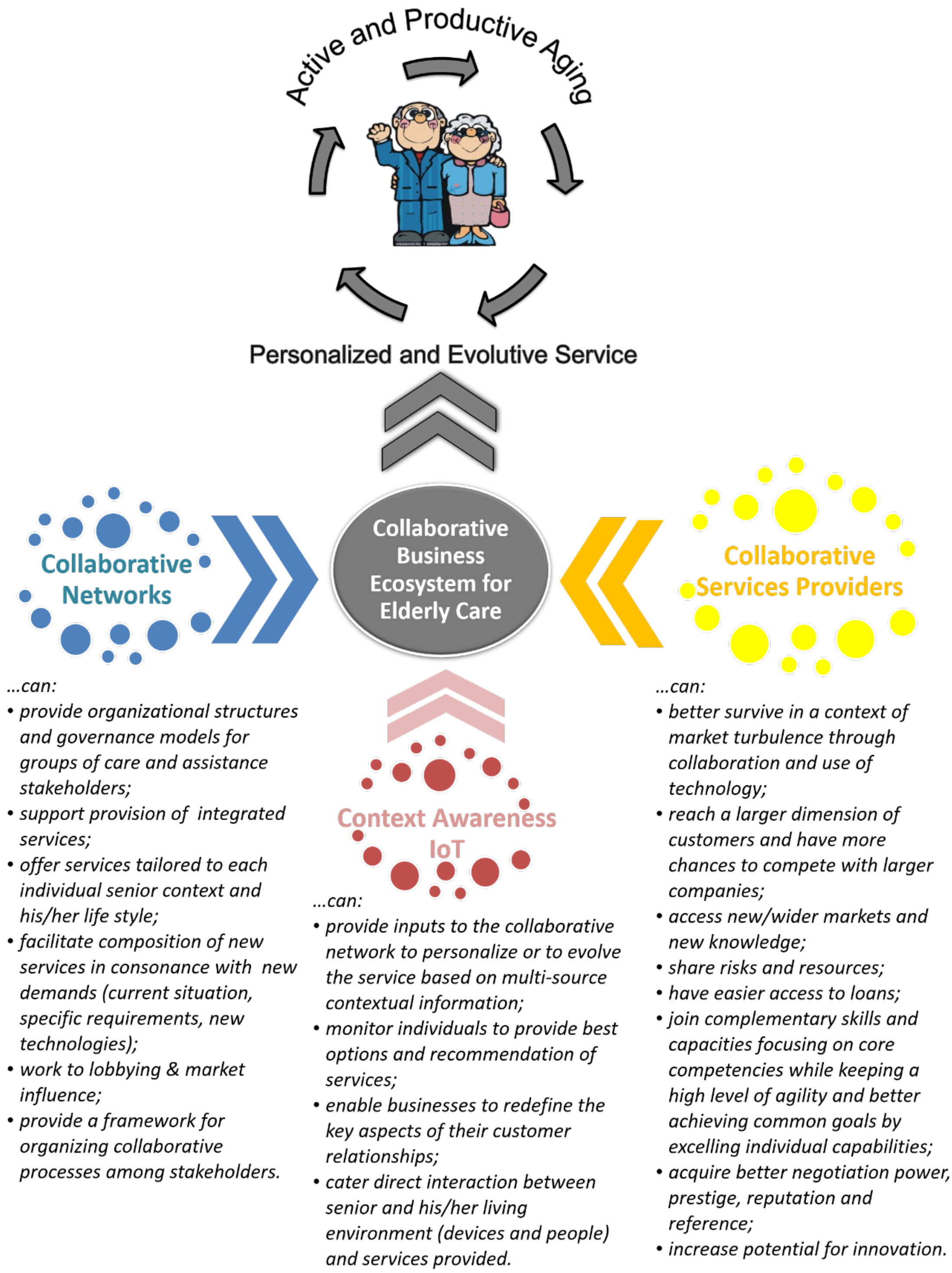


Figure 2.13: Summary of Background and Literature Review

This overview sets the context for the proposals in this work.

3

Elderly Care Ecosystem Conceptual Model

This chapter introduces a conceptual model for the Elderly Care Ecosystem (ECE) framework. This model provides relevant information for service composition and personalization processes that will be presented in the next chapters. The concept of ECE is supported by a computer-supported collaborative environment that allows the combination of services potentially involving multiple providers to seek a better fit with senior's care needs. The concepts and relationships are generally presented using UML class diagrams and descriptions using natural language. Then, a formalization of the model is presented to provide more accurate definitions of the main concepts and relations used during the service composition, personalization and evolution processes.

3.1 Elderly Care Ecosystem

An *Elderly Care Ecosystem (ECE)* is a particular case of a collaborative business ecosystem. It includes various elements of a collaborative environment (administration, broker, virtual organization, planner, and coordinator), and specific elements that characterize it as an "Elderly Care Collaborative Network", namely the seniors (customers), their requests and requirements, care needs, care services, and service provider entities, among others (Baldissera et al., 2017a; Baldissera & Camarinha-Matos, 2016a, 2016b). Figure 3.1 presents the partial (high-level) conceptual model of an ECE. The shaded part of the diagram represents common elements of a collaborative environment management system and the outside elements are those specific of the ECE.

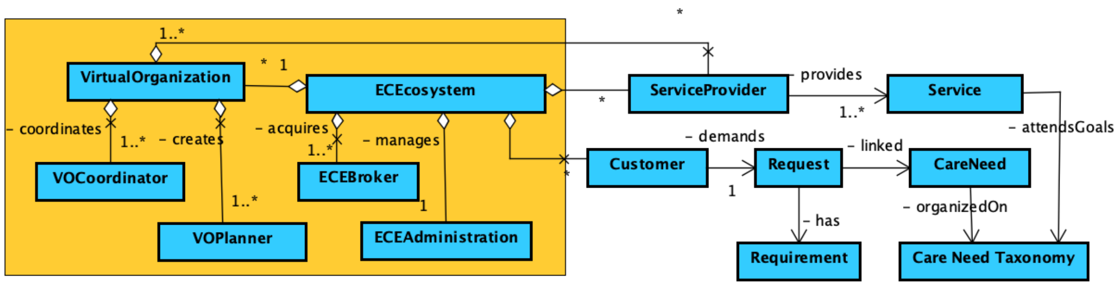


Figure 3.1: ECE partial (high-level) conceptual model

ECEcosystem represents the core entity in ECE. It is responsible for managing the entire ECE and guaranteeing that the execution policies established by the administrator (*ECEAdministration*) are enforced. *ECEAdministration* is the entity responsible for the ECE operation and evolution, which includes tasks such as registration of providers and customers, contract formalization, conflict resolution process, decision support management, etc. *ECEBroker* represents an ECE member that is responsible for identifying and acquiring collaboration opportunities.

A *VirtualOrganization* (VO) represents a temporary alliance of organizations that share resources and skills and come together to deliver an integrated care service. *VOPlanner* represents a business integrator, who is responsible for planning, designing, and launching a new goal-oriented networks by creating new VOs. This role usually supports the response to an opportunity identified by an ECEBroker. A *VOCoordinator* is a person or an organization that manages a VO.

To explain the other elements, the ECE environment domain diagram (see Figure 3.2) highlights four ECE subsystems: ECE Manager System, ECE Information System, ECE Personalization System, and ECE Evolution System, and the three phases involved in the operationalization of ECE: Preparation, Execution, and Monitoring.

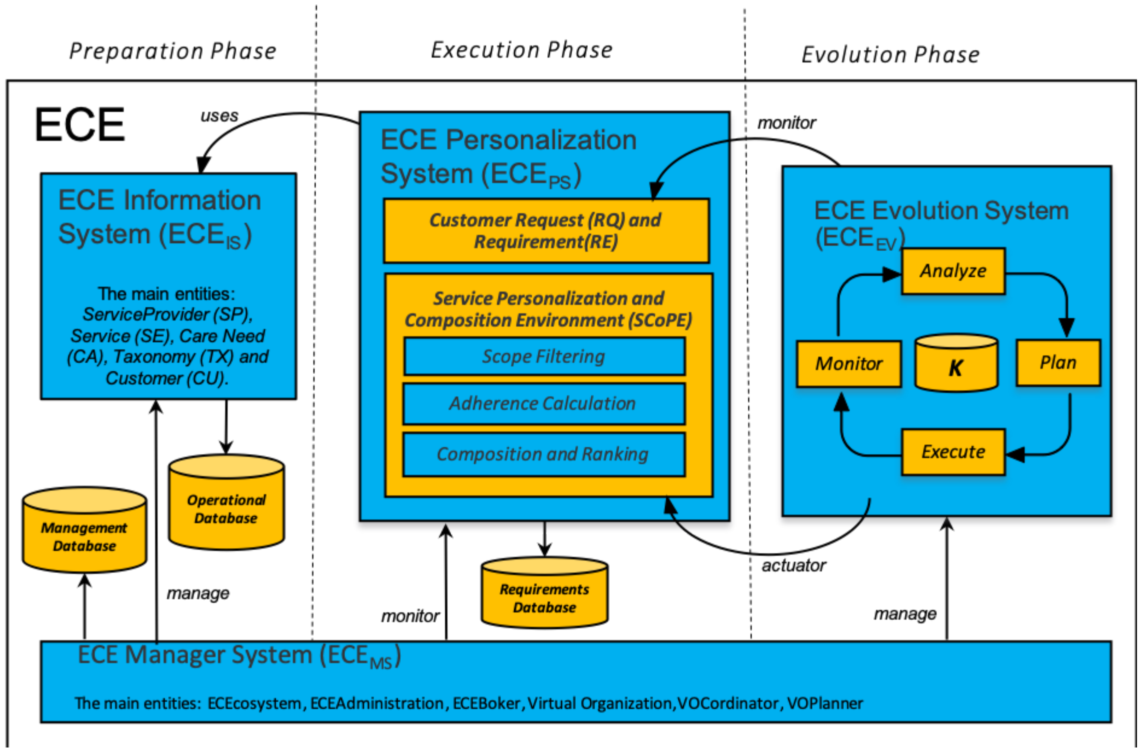


Figure 3.2: ECE environment domain diagram

The *Preparation phase* corresponds to the creation of ECE and definition of its rules and functionalities within a collaborative environment. It involves representing the main body of information and knowledge, identifying the target audience, the involved stakeholders, namely partners in the various groups (support entities, regulation entities, private companies, governmental institutions, freelancing professionals, caregivers, etc.) which are members of ECE, ICT and human resources, business and management rules; and characterizing the available services. Based on the templates proposed in this chapter, this phase involves creating the taxonomy of care need goals, and identifying the service provider profile, service profile, and customer profile. The main subsystems responsible for the *Preparation phase* execution are *ECE Manager System* (ECE_{MS}) and *ECE Information System* (ECE_{IS}). ECE_{MS} is based on the pillar of collaborative networks. ECE_{IS} is more detailed in the next sections in the current chapter.

The *Execution phase* relates to the process of composition and personalization of services, including the ranking of the offered pairs (services and service providers). The main actuator subsystem at this stage is *ECE Personalization System* (ECE_{PS}) which involves the Service Composition and Personalization environment (SCoPE method). This method is based on three steps: scope filtering, service adherence calculation, and service composition and ranking, as detailed in Chapter 4.

The *Monitoring phase* resorts to the *ECE Evolution System* (ECE_{EV}) that supports the service evolution and monitoring. ECE_{EV} materializes the Service Evolution (SEvol) method. Considering the dynamic environment and stages of life, the *ECE broker* analyses the situation (in collaboration with the relevant stakeholders) and adapts the services to fit each new context. In this way, SEvol evolves an existing care solution to cope with the new phase of the customer's life (for instance, handling new or obsolete care needs, new customer inputs, technological changes, new strategies of service providers, etc.). The detailed process of the self-adaptive system approach for service evolution into ECE (ECE_{EV} and the SEvol method) is presented in Chapter 5.

3.2 ECE Information System

ECE Information System (ECE_{IS}) is the component that maintains the ECE information objects. Specific ECE objects (e.g. customer, care needs taxonomy, service, and service provider) that are fundamental for ECE operalization are detailed in the following sections.

3.2.1 Domain Analysis

The customer's profile evaluation is particularly relevant for service selection. Identifying the needs and wishes of the customer can guide the identification of potential services that attend his/her particular specificities. A number of research projects on ICT and aging were analysed regarding their contribution to the requirements elicitation process. From the results of these projects, which included extensive field analysis, we could identify a set of requirements for designing ECE.

In this analysis we particularly feature the ePAL project (Extending Professional Active Life), which established "a strategic research roadmap focused on innovative collaborative solutions and ensuring a balanced post-retirement lifestyle" (Camarinha-Matos & Afsarmanesh, 2011), the BRAID project (Bridging Research in Ageing and ICT Development) (Camarinha-Matos et al., 2013a) which has built a "comprehensive RTD roadmap for active ageing by consolidating and extending existing roadmaps in close interaction with relevant stakeholders", and the AAL4ALL project (Ambient Assistance Living for All), which conducted a large "field survey aimed at both characterizing current users of AAL technologies" (Camarinha-Matos et al., 2015).

In addition, a report published by the European National Insurance (Perista et al., 1998) and a survey on home care services conducted by Santa Casa da Misericórdia de Lisboa (SCML, 2010) were used as the baseline for elderly profile identification.

In the next sections, further details on the key features of the Elderly Care Ecosystem and their relations are provided through partial UML class diagrams and mathematical formalisms regarding the customer, care needs, services, and service provider environments. Successive refinements of the model may detail entities with properties. However, at this level, we are focused on the main concepts of ECE, without concerning about attributes and potential operations on each entity.

3.2.2 Customers Environment

A *Customer* (CU) represents an individual customer (elderly) with a unique profile. An elderly profile is composed of fixed and variable sets of data representing distinct areas of the persona. Figure 3.3 presents the main informational elements identified in ECE to build a customer profile. Currently, it is composed of six elements, namely *Personal Data*, *Special Condition*, *Life Style*, *Resource*, *Geographical Area*, and *Guardian*. *Personal Data* include inputs about personal data, *Education*, *Health*, *Family*, *Profession*, and *Personality*. *Life Style* comprehends dimensions such as *Independend Living*, *Culture*, *Social aspects*, *Recreation*, *Technology*, and *Religion*. The elements of the customer profile are described in details in Table 3.1.

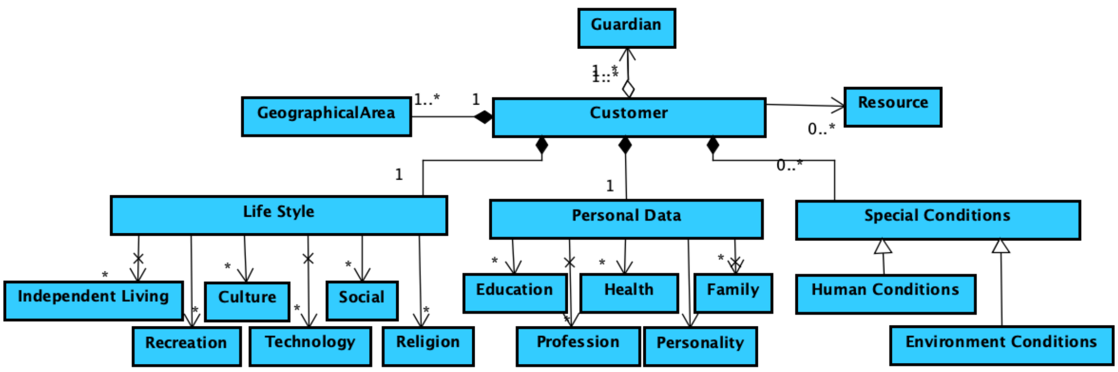


Figure 3.3: Customer Profile Characterization Diagram

Table 3.1: Customer´s profile elements

Class	Description
Customer	Describing the profile of the senior. This element includes typical identification features (e.g. name, birth date, gender, etc.) and elements of general information about customer's daily life. A historical record can enrich the profile.
Geographical Area	Representing the customer's localization information (e.g. home address, children´s address, everyday local address, etc.).
Life Style	Indicating customer´s individual life style (e.g., how daily routines are, customer´s likes, and dislikes, cultural aspects, spiritual aspects, etc.). The life style identification contributes to enriching the profile and assisting in the searching for best services during the personalization and evolution processes.
Independent Living	Indicating customer´s independence level (e.g. whether the elderly lives alone, depends on someone, lives on a nurse house, is able to drive or not, goes out alone, etc.).
Recreation	Describing customer´s leisure activities and their frequency (e.g. sports, travels, walks, etc.).
Culture	Describing customer´s cultural activities and their frequency (e.g. favorite movies, theatre, kind of preferred museums, preferred games, etc.).
Technology	Representing how the elderly deals with technology in his/her daily life (e.g. if he/she is willing to use more technology, enjoys innovations, has a computer, has internet access, has a smartphone, and other technological devices).
Social	Indicating customer´s social aspects that capture how the elderly relates with other people (e.g. social networking activity, groups belonging, etc.).
Religion	Involving information about customer´s religious and faith issues that might affect care services (e.g. customer´s belief restrictions, prohibited procedures, etc.).
Personal Data	Relevant information about the customer´s environment (e.g. educational and professional activities, family structure, etc.).
Education	Education data (e.g. education degree, specialization area, place, etc.).

Profession	Describing acquired professional experience (e.g. jobs and positions, if the elderly is retired or still working, etc.).
Health	Dimension related to personal health (e.g. the need of taking regular medicines, use of special equipment, insurance plans, etc.).
Personality	Representing customer's personality profile, behavioral issues which can influence future choices and directions (e.g., status humor, striking characteristics, individual peculiarities, if customer is sociable, moody, rigid, pessimistic, etc.).
Family	Indicating family structure (e.g. the customer has children, brothers, sisters, caregivers, best friends, etc.).
Special Conditions	Referring to limitations that an elderly might have, namely human and environment constraints.
Human Conditions	Indicating human limitations covering: (a) cognitive limitations (e.g. memory and attention loss, personal vulnerability or deficit of language comprehension, etc.); (b) physical limitations (e.g. loss of sensitivity on the hands and sensory and motor deficits, etc.); (c) diseases limitations (e.g. depression, heart issues, diabetes, Alzheimer, etc.).
Environment Conditions	Indicating environment limitations comprising: (a) financial limitations (e.g. salary, pension, debts, etc.); (b) accessibility limitations provided by the physical environment (e.g. high walkability and access to parks and green places, etc.); (c) security limitations (e.g. no safe transportation, home security loss, etc.).
Guardian	Referring to the person responsible as alternative contact for the customer or the one that is responsible for more relevant decisions (e.g. a tutor, a relative, a friend, a caregiver, or combination of them).

To some extent, some of customer's data profile might be considered intrusive. Thus, it is essential to establish and enforce privacy policies on ECE's, which should be conciliated with existing ethical and data protection rules, such as the General Data Protection Rules (GDPR) of the European Union. Nevertheless, despite of its importance, the discussion of privacy is out of the scope of this research work.

To compose and personalize services, customers must indicate requests and requirements, which are detailed in Section 3.3.

3.2.3 Care Needs Environment

A *Care Need* (CA) corresponds to current customer's wishes and care requirements. The proper identification of customer´s care needs as well as priorities is very important in order to find adequate care services. In general, a care need is expressed in natural language, which makes it notably difficult to automate the process of finding providers for a particular need. Therefore, a care need requires a structured representation to support automation. We classify care needs in higher-level abstractions based on a taxonomy of care need goals (TX) (for which a partial example is shown in Figure 3.4).

Each care need might be covered to some extent (i.e. by some coverage level) by available care services in the ECE. Furthermore, each care need is associated with the impact it might have on another care need. An ECE has only one TX that is maintained by the *ECEAdministration*. It has the responsibility to remove, add, and update the TX for the proper execution of the ECE processes.

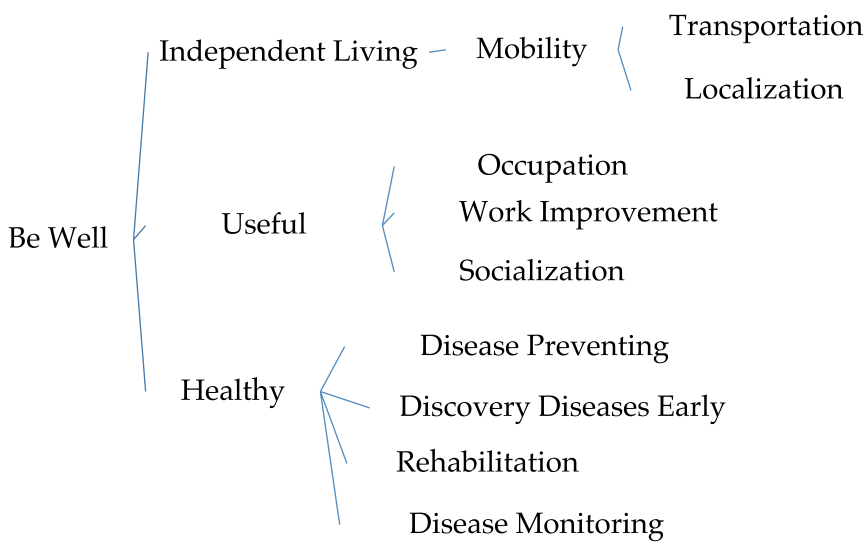


Figure 3.4: Example of Care Need Taxonomy (Partial Illustration)

In the example shown in Figure 3.4, the main care needs goal for elderly is *Be Well* and its sub-needs are *Independent Living*, *Useful*, and *Healthy*. Considering the four life settings (proposed by the BRAID Project), we joined *Occupation in life* and *Recreation in life* into the single goal *Useful* (the same set of services), which for our purpose is enough.

Independent Living represents aspects of the elderly's life he/she would like to control during his/her aging. For example, controlling the walking capability by himself/herself or going shopping without depending on a family member. *Useful* represents the feeling of being connected and useful to the surrounding community by contributing to something larger than himself/herself. Finally, *Healthy* corresponds to health improvements and longevity, reducing the risks of disabilities.

These goals are essential to enable the elderly doing things he/she values most. These goals enable elderly people to age safely in a place that is adequate for them, continue their personal development and contribution to their communities, while retaining their autonomy and well-being during aging.

The main aspect related to the taxonomy is to be able to associate care needs and services at specific levels of the taxonomy tree in such way they can be processed by ECE. The upper the node is in the tree the more abstract the concept is. For example, if a care need is associated with the *Mobility* node, all services associated with this node are also supposed to attend its children *Transportation* and *Localization* nodes.

The concepts related to care needs and their detailed descriptions are shown in Figure 3.5 and Table 3.2 respectively.

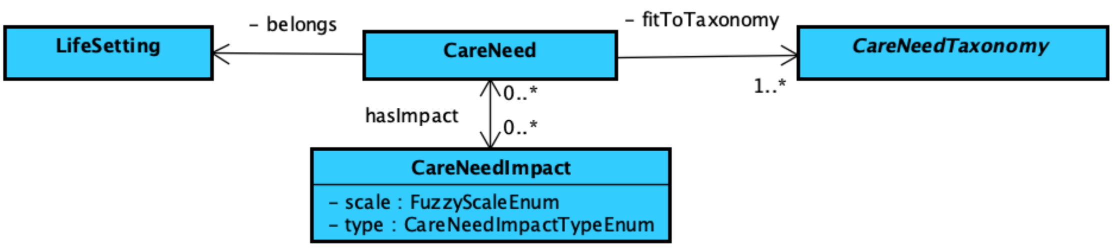


Figure 3.5: Care Needs Characterization Diagram

Table 3.2: Care Need´s elements

Class	Description
CareNeed	Representing current customer's care need. It is characterized by: name and description.
LifeSetting	Indicating which of the three areas to which care needs are associated: *Independent Living*, *Useful*, or *Healthy*.

CareNeedTaxonomy	The care needs taxonomy to which each care need is mapped to. It is composed of a hierarchy of nodes (care need goals).
CareNeedImpact	Indicating the impact that a care need might have on another care need. The impact can be a negative or positive influence (e.g. when a senior needs *Physical Support*, this situation influences negatively *Transportation,* and positively *Localization).* In addition, the impact level can be expressed on a fuzzy scale (e.g. from *very low impact* to *very high* impact).

Services are linked to nodes of the care needs taxonomy indicating the level of care needs they cover. It is however important to notice that the notion of "need's coverage" is not a binary concept; rather we can identify degrees of coverage. Therefore, ECE services have a coverage level regarding the care needs they are associated to. This level is expressed on a fuzzy scale (e.g. from *very low* to *very high*). This range is established based on a number of factors, including the field experts' experience, the customer's feedback, and indication of the service provider, or a combination of them (depending on the ECE management strategy).

ECE is assumed to provide an adequate taxonomy of services along with proper mechanisms to avoid unfair provider selection. For instance, discriminatory strategies can be induced when service providers only associate their services to high-level nodes to increase their chances of being selected during a bid process. To ensure fair play, ECE must consider multiple parameters for selection, such as reputation, the experience of the provider as a participant in the VO, its expertise, etc.

3.2.4 Services Environment

A Service (SE) can be either atomic (involves a single business process) or integrated (combining several other services). It is provided by a service provider (or alliance of service providers) and it is part of the ECE services repository.

Service characteristics include a description as well as a service rating, geographical area of service coverage, associated service business process, applicability constraints, application suggestion which can strengthen preferences of the customer, necessary or provided resources, etc.

When a provider adds a service to the ECE repository, the ECE manager suggests a level of coverage for a particular care need related to the care need goals taxonomy. From the third level of the example shown in Figure 3.4, services can be associated to nodes of the taxonomy of care need goals.

Each available service in ECE is expected to attend one or more care needs. Figure 3.6 shows the proposed service characterization. Its detailed description is given in Table 3.3.

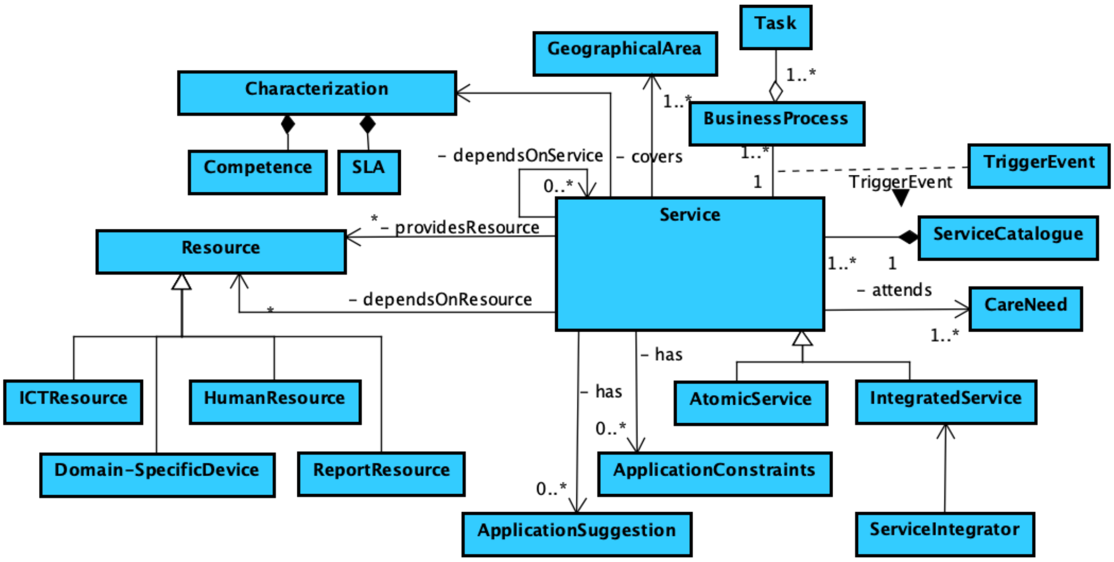


Figure 3.6: Service Characterization Diagram

Table 3.3: Service´s Elements

Class	Description
Service	Representing an atomic or integrated service provided by service providers. A service has a rating provided by the customer and by the ECE management system. A service can be dependent on another service (e.g. a *Health Monitoring* service depends on *Transportation* service that takes the customer to a medical clinic).
GeographicalArea	Representing localization of service coverage. A service might have one or more geographical coverage areas (e.g. Latitude: 38.7071, Longitude: -9.13549, 38 ° 42'26 "North, 9° 8'8" West, about Lisbon).
BusinessProcess	Indicating a collection of linked, structured events and tasks that produce a specific service (e.g. to transport the senior to a medical appointment it is necessary to know the appointment schedule as well as the place of collection and delivery of customer). A service is

	associated with one or more business processes.
Task	Indicating activities executed by a business process, corresponding to human or software services (e.g. a nurse applies an injection, device sends a reminder, etc.).
TriggerEvent	The event that triggers a service request (e.g. identify current location of senior, verify suitable professionals for the task, etc.).
ServiceCatalogue	Representing a repository of services available on ECE. Services are kept in a catalogue based on three life settings (described earlier) available for consultation when required.
AtomicService	Indicating a service that has a single business process.
IntegratedService	Indicating a business service which consists of a combination of several other services that turns this combination into a new service.
ServiceIntegrator	Describing an entity that performs services integration. One service may depend on another service, or complement it, stimulating services integration.
ApplicationConstraints	Indicating a situation in which the service cannot be provided, indicating restrictions (e.g. a service that is not suitable for those with visual impairment, for seniors over 90 years old, etc.).
ApplicationSuggestion	Indicating a suggestion of additional service(s) that can strengthen the response to the preferences of the customer (e.g. suggesting *friendship* indicating that the service is appropriated for strengthening friendship ties and its relations, suggesting *culture* representing that the service strengthens cultural activities, etc.).
Resource	Representing capabilities that are required (input) by a service or provided by a service (output). A service can provide a resource (e.g. a *Localization* service provides a bracelet that can interact with other resources, for instance sending alerts to current social network of friends nearby). On the other hand, a service can be dependent on a resource (e.g. a *Localization* service depends on a smartphone, or a *Health Monitoring* service depends on a nurse to measure blood pressure.
ICTResource	Describing information and communication technology resources (e.g. Wi-Fi internet, data analyis tool, etc.).
DomainSpecific Device	Describing devices used in a specific domain (e.g. a bracelet, a sensor, etc.).
HumanResource	Describing human resources (e.g. a nurse, a friend, a

	driver, etc.).
ReportResource	Describing specific data necessary on time (e.g. localization where the service will be delivered, information about senior´s humor to suggest activities, etc.).

3.2.5 Service Provider Environment

A Service Provider (SP) represents an organization, member of ECE, that provides care services. The profile of this entity typically includes attributes such as name, description, main actuation area, organization interests, market influence and experience, responsible person, trustworthiness information, competencies and skills, etc.

Providers are part of ECE and deliver care and assistance services to attend care needs. In a collaborative environment, service providers can join with others to provide integrated services and improved delivery of personalized services. Figure 3.7 shows a model for the service provider with a detailed description of its attributes in Table 3.4.

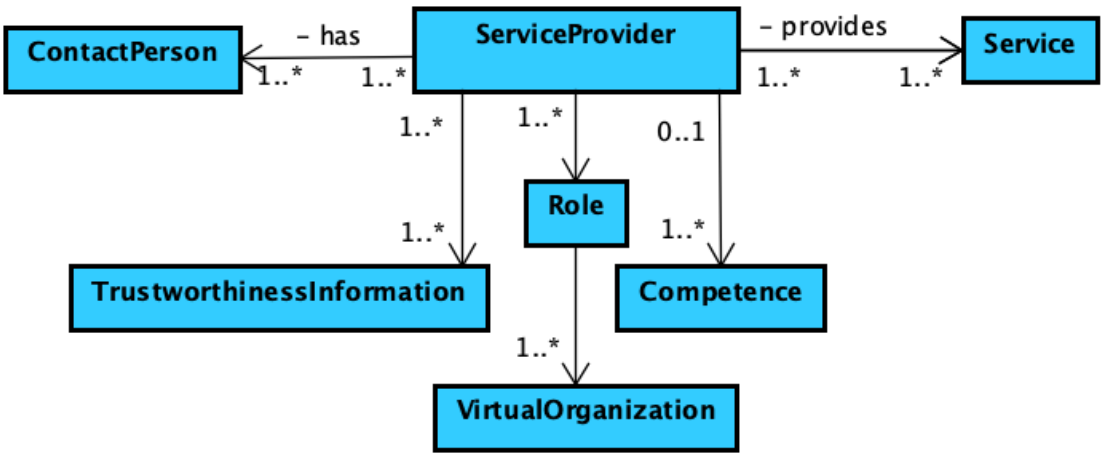


Figure 3.7: Provider Characterization Diagram

Table 3.4: Service Provider Description

Class	**Description**
ServiceProvider	Characterizing an organization that provides services. This entity includes typical identification features (e.g. name, description, main actuation area, organization interests, market influence and experience, etc.).

	Furthermore, service providers are classified according to the nature of the provider (e.g. regulation entity, support entity, service provider entity, etc.) and their category (e.g. private, public, non-governmental institution, mixed, etc.).
ContactPerson	Indicating a person (one or more) responsible for being the organization's contact with ECE (e.g. main manager, project manager, business manager, etc.).
TrustworthinessInformation	Describing the service provider trustworthiness information. This entity is composed of a rating provided by customers and a reliability level provided by ECE management (e.g. 4.7/5.0 and very reliable).
Role	Indicating member's type in ECE taking into consideration the collaborative environment. Each service provider may play one role (or more) in the ECE (e.g. broker, virtual organization coordinator, virtual organization participant, etc.). This information covers the current and past organization's roles (e.g. the service provider can be coordinator and participant in a virtual organization and broker on another one).
VirtualOrganization	Representing a temporary alliance of service providers that come together to share skills or core competencies and resources to better deliver integrated care services.
Competence	Describing service provider's capability and capacity for care service provision (e.g. business and entrepreneurial skills, technological skills, motivational and interpersonal skills, communications skills, corresponding capacity, etc.).

3.3 ECE and Related Definitions

As described previously, an Elderly Care Ecosystem *(*ECE*)* can be considered a particular case of a collaborative business ecosystem, specially designed to support the management of service providers, services, and customers (elderly people and relatives). The main idea of ECE is to have an environment to facilitate the personalization, composition, and evolution of care services. To build the ECE framework, a number of information elements is necessary. This information fundamentally describes available services and providers in the ECE, the customers, and the care needs/goals taxonomically organized. In the following, we restate the fundamental definitions of this model with a mathematical formalism which is used during the description of the personalization and composition subsystem and evolution subsystem.

Definition 1. ***Elderly Care Ecosystem (ECE)***

represents the system that supports the creation and management of virtual organizations to attend customer's needs as well as the necessary support information. In other words, a kind of breeding environment for virtual organizations in elderly care. An ECE is composed of four subsystems, defined as:

$$\mathrm{ECE} = < \mathrm{ECE_{MN}}, \mathrm{ECE_{IS}}, \mathrm{ECE_{PS}}, \mathrm{ECE_{EV}} > \quad (1)$$

where $\mathrm{ECE_{MN}}$ is the management subsystem that administers the ECE environment, $\mathrm{EC_{IS}}$ is the information subsystem that maintains the ECE entities and objects, $\mathrm{ECE_{PS}}$ is the personalization subsystem that analyses the customer profile and ranks potential services and service providers to attend the requirements, and $\mathrm{EC_{EV}}$ is the evolution subsystem that identifies opportunities for service evolution and monitors the customer requests. $\mathrm{ECE_{MN}}$ is based on the principles of collaborative networks.

$\mathrm{ECE_{IS}}$ is described as:

$$\mathrm{ECE_{IS}} = < \mathrm{VO}, \mathrm{SP}, \mathrm{SE}, \mathrm{CU}, \mathrm{TX} > \quad (2)$$

where VO is a set of virtual organizations existing in the ECE, SP represents the service providers available in the ECE, SE is the set of services offered in the ECE, CU the set of customers, and TX is the taxonomy of care need goals, which is unique for the ECE, but at the same time dynamic.

$\mathrm{ECE_{PS}}$ is described as:

$$\mathrm{ECE_{PS}} = < \mathrm{RQ}, \mathrm{RE}, \mathrm{SCoPE} > \quad (3)$$

where RQ is the set of customer's requests, RE the set of customer's requirements, and SCoPE is a method to compose and personalise services to a customer. This method is presented in Chapter 4.

$\mathrm{ECE_{EV}}$ is described as:

$$\mathrm{ECE_{EV}} = < \mathrm{cu}, SE\_of, \mathrm{SEvol} > \quad (4)$$

where cu the customer, SE_of the solution resulting from the SCoPE process (more detailed in Definition 9) , and $SEvol$ is the service evolution process detailed in Chapter 5.

Definition 2. ***Virtual Organization (VO)***

represents an alliance of independent organizations sharing resources and skills that collaborate to achieve a common goal (Afsarmanesh & Camarinha-Matos, 2007; Camarinha-Matos & Afsarmanesh, 2008a; Kaletas et al., 2005). In this context it represents a temporary consortium of organizations that come together to deliver an integrated care service. We define a particular vo ϵ VO as:

$$vo = < SP_{vo}, SE_{vo}, cu_{vo}, RQ_{cu} > \tag{5}$$

where $SP_{vo} \subset SP$ is a set of service providers, SE_{vo} is a set of services provided by SP_{vo}, $cu_{vo} \subset CU$ represents a customer, and RQ_{cu} the customer's requests.

Definition 3. ***Service Providers (SP)***

represents a set of organizations (physical or virtual) that provide care services. Therefore, the relation SP-r-SE: $SP_{vo} \rightarrow SE_{vo}$ holds. A service provider is characterized by one or more areas of actuation AR and its trustworthiness rating tr. Thus, a service provider sp ϵ SP is defined as:

$$sp = < AR_{sp}, tr > \tag{6}$$

where $AR_{sp} \subset AR$ represents a set of actuation areas, and $tr: [1..5]$ is the trustworthiness of the service provider. We assume that $AR = \{\text{independent living, useful, healthy}\}$. Trustworthiness is given by a combination of the rating given by customers and the reliability level of the service calculated by the ECE framework management. The scale assumes 1 as the lowest and 5 as the highest level of trustworthiness.

Definition 4. ***Services (SE)***

represents the set of services offered in ECE. Each service represents a business value provided to a customer by a service provider (Sanz et al., 2006). A service can be either atomic or integrated (combining several other services). Service characteristics include service goals, service rating, geographical area of coverage, a business process, applicability constraints, suggestions of application to strengthen the preferences of the customer, and necessary or provided resources. A service se ϵ SE is defined as:

$$se = < SE', G_{se}, AC_{se}, rep > \quad (7)$$

where $SE' \subset SE_{sp}$(services provided by service provider SP) , $G_{se} \subset G$ is the set of goals the service attends based on the taxonomy of care needs (see Definitions 6 and 7), and AC_{se} is a set of restrictions applied to the provision of the service. The set SE' is the set of dependent services, where $SE' = \emptyset$ indicates the service is atomic, otherwise it is integrated. Service restrictions are applied considering a predefined restriction list LI for the ECE. Thus, we assume that $AC_{se} \subset LI$. The reputation of a service (rep) is expressed by a value in the scale 1…5, where 1 represents the lowest reputation and 5 the highest one. We assume that there is a system that computes the reputation of the service.

Definition 5. ***Customers (CU)***

represents the set of entities that consume the services provided by the VOs in ECE. Each customer is associated with a unique profile that follows a template configured by the ECE administrator. Typically, a template includes personal data, lifestyle aspects, customer's limitations and general data. A customer cu ϵ CU is defined as:

$$cu = < P(\tau), C > \quad (8)$$

where P(τ) is a customer profile based on a template τ, C is a set of conditions and relevant individual constraints.

The template τ involves the main information elements identified in ECE to build a customer profile (previously presented in section 3.2.2). The conditions C involve, for instance, information about one or more locations to deliver the service (described by geographical area), the limitations that an elderly might have, namely human and environment constraints (if these exist), identified as special conditions: for instance the maximum investiment and the presence of chronic diseases.

Definition 6. ***Taxonomy of Care Need Goals (TX)***

representing a taxonomy of care need goals used in a specific ECE. A taxonomy TX is defined as:

$$TX = < \mathrm{G}, G_p, G_r > \quad (9)$$

where G represents the goals, $\mathrm{G_p} \subset \mathrm{G} \times \mathrm{G}$ represents a parent relation between two goals, and $\mathrm{G_r} = \mathrm{G_p^{-1}}$ is the inverse relation of parent relation representing refinement relations. Given $\mathrm{g1}, \mathrm{g2} \in \mathrm{G}$, the following formula holds:

$$(g2, g1) \in G_r \iff (g1, \mathrm{g2}) \in G_p \wedge g1 \neq g2. \quad (10)$$

Figure 3.8 illustrates the care needs taxonomy adopted in ECE. This taxonomy of care needs is used by customers to map their requirements to a certain goal level and by service providers to indicate which goals they can attend based on the services they are declaring in ECE. For example, the need for social relationship expressed by an elderly (customer) could be mapped to the node *Useful* → *Occupation/Socialization* → *Entertainment/Relationship*. Similarly, a service provider that offers health services in the rehabilitation area can map a service to *Healthy* → *Cognitive Rehabilitation*, for instance.

Goals (G) can be abstract or concrete. Abstract goals are only informational and cannot have any direct association with customer care needs or services. The higher the goal in the hierarchy the more abstract it is. Thus, top goals are devoted to express broad intentions declared by customers and service providers. The nodes representing goals in the taxonomy are managed by the ECE administrator that updates the taxonomy by adding/removing, enabling/disabling nodes according to emerging categories of care needs and services. The taxonomy is used during the process of ranking service providers.

Definition 7. ***Care Needs (CA)***

represents a set of goals related to the care needs taxonomy associated with a relevance scale. We define a care need $\mathrm{ca} \in \mathrm{CA}$ as:

$$ca = < g, rl >, \quad (11)$$

where $\mathrm{g} \in \mathrm{G}$ is a goal in the taxonomy TX, and $\mathrm{rl} \in \mathrm{FU}$ is the relevance degree of the goal for the customer. We adopt a fuzzy scale for $\mathrm{FU} = \{\mathrm{very\ low}, \mathrm{low}, \mathrm{medium}, \mathrm{high}, \mathrm{very\ high}\}$.

When the customer expresses his/her request and care needs, the identified TX nodes are activated (for identifying the potential {service, provider} pairs) for this customer. When a provider registers a service into the ECE, it suggests a level of coverage (CO) for a particular goal (or more than one) in the taxonomy of care need goals.

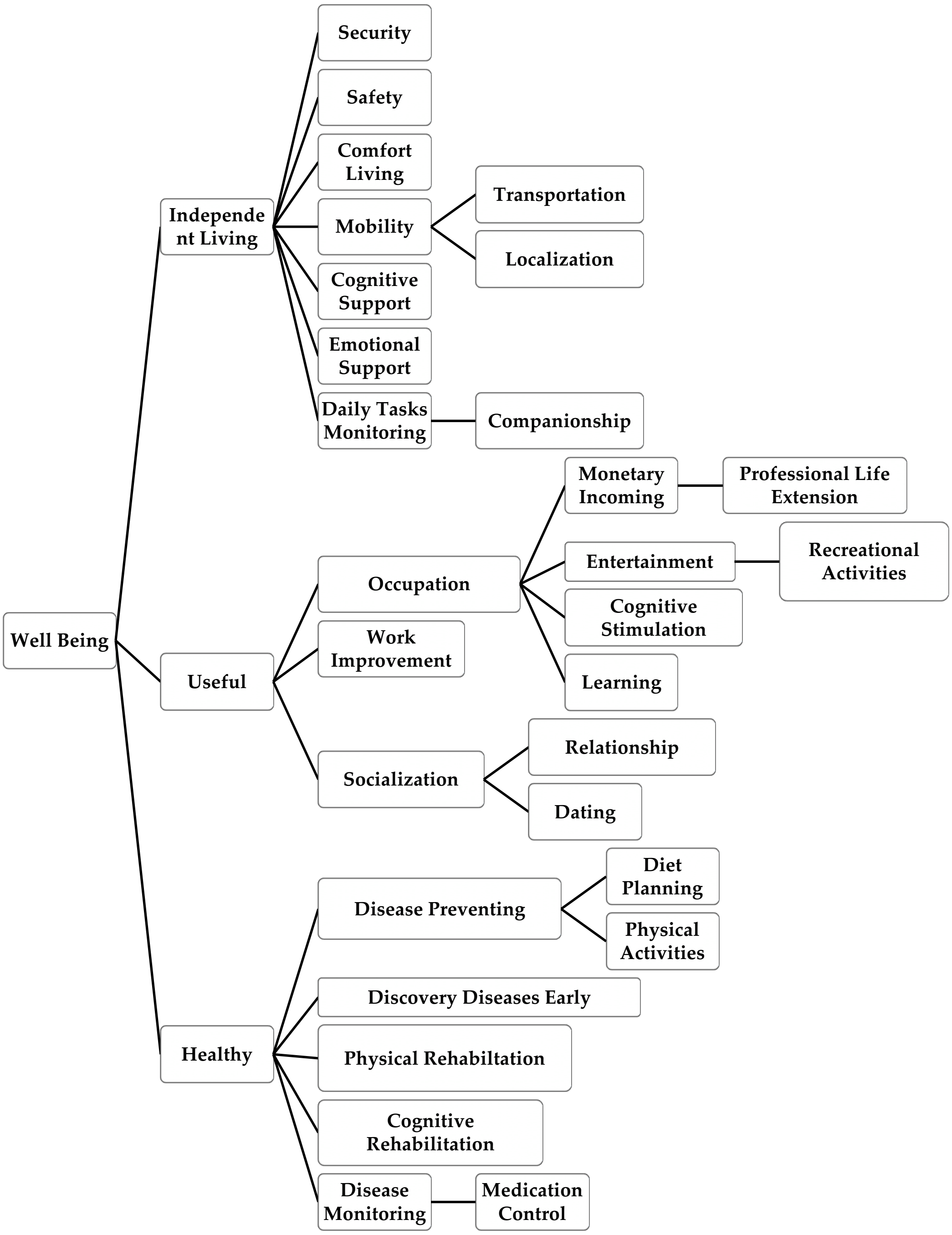


Figure 3.8: Partial taxonomy of care need goals of the Elderly Care Ecosystem

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Definition 8. ***Request (RQ)***

represents a solicitation of services made by a customer. We define a request rq $\in$ RQ as:

$$rq = < cu, ca, RE >, \quad (12)$$

where cu is the customer, ca is a care need (ca = < g, rl >) and RE is a set of requirements for the care need ca. A requirement represents constraints applied to the request. For example, a customer may request a health service and one of the requirements is to provide it in the geographical location chosen by the customer. Requirements are described in terms of logical expressions. Formally, we define a requirement re ∈ RE as:

$$re = < id, ty, lo, va >, \tag{13}$$

where id is a label identifying the name of the requirement (e.g., location), ty ∈ TY is the type of requirements, lo is a logical operator and va is the value to be considered in the expression. The label that identifies the requirement is provided by ECE according to pre-determined variables associated with the taxonomy of care need goals. Requirements are considered soft or hard, thus TY = {soft, hard}. A hard requirement eliminates the services that evaluate the expression as false, e.g., those that do not attend the requirement imposed by the customer. If the requirement is soft the service is not eliminated during the ranking process even if it fails to satisfy the requirement. Logical operators supported by the current implementation include "=" ,"<> "," < "," ≤ ", ">", and " ≥ ". Finally, value *va* can be crisp (number, string, etc.) or fuzzy (depending if the requirements are expressed in crisp value or fuzzy scale).

Definition 9. ***Service Offer (SE_of)***

represents a potential service that can attend a customer request.

$$SE\_of = < sp, se, cu, rq, adherence > \tag{14}$$

where sp represents a service provider, se is a service, cu represents a customer, rq represents a customer's request, and adherence is a compatibility index relating the customer profile, requirements and priorities to the providers' characteristics and care services features. It represents a combined view of fitness between the considered service and the individual care need. It is determined by a ranking algorithm, through a comparison between the request and the offer of services. More details about the ranking process are shown in Chapter 4.

3.4 Summary

Bearing in mind that this work focuses on the aging processes, this chapter presented a conceptual model of an Elderly Care Ecosystem (ECE) based on the notion of collaborative networks. The collaborative networks discipline is considered a relevant area that provides support to integrate multi-provider business services and support the composition of personalized care services, in order to offer provision of services to individual seniors.

In this sense, ECE framework is proposed to be based on four subsystems: $\mathrm{ECE_{MN}}$, $\mathrm{ECE_{IS}}$, $\mathrm{ECE_{PS}}$, and $\mathrm{ECE_{EV}}$, and the main elements: customer, care needs, service providers, and services. Dynamic care needs taxonomy as part of the personalization process, represents a common "language" to identify services and needs.

These concepts are detailed through UML diagrams and elements' descriptions. Definitions are mathematically conceptualized and the three main processes of ECE are presented in the following sections: Preparation (ECE start); Execution (personalization process: Chapter 4); and Monitoring (evolution process (Chapter 5)).

4

Service Personalization System: SCoPE Method

This chapter presents the approach to the Service Composition and Personalization Environment (SCoPE). Related aspects of the ECE environment are described and a customer profile template is proposed in the context of a collaborative network domain. ECE provides the context for the personalization method which is based on the matching between a taxonomy of care needs and {service, provider} pairs, and the calculation of a service adherence index to identify suitable services and corresponding providers. Then, SCoPE is presented highlighting its key steps: scope filtering, service adherence calculation, and service rating and composition. For this purpose, a number of algorithms are introduced, and a practical application case is discussed through all chapter.

Considering that the personalization subsystem involves identifying customer request and requirements, as well as ranking potential services and service providers to attend them, basic data on the customer profile are presented before introducing the SCoPE method.

4.1 Customer Profile

The customer's profile identification reinforces that each person is treated individually. Along with the process of customer's request (RQ) identification, it includes characterization of current care needs (CA) and their respective relevance (RL), guiding the choice of the most promising services to attend these care needs (personalization process).

4.1.1 An Application Scenario

Considering the requirements elicitation process (described in section 3.2.1), a number of research projects on "ICT and aging" were analyzed from which a set of requirements were identified for the customer profile. A typical scenario involving a senior man, Mr. Silva, who has some personal care needs is used to illustrate the applicability of the proposed ECE customer profile and request identification process (see Table 4.1).

Table 4.1: Illustrative Scenario.

<table>
<tr><td></td><td>Personal Data.
Name: João Silva
Gender and age: male, 82 years old.
Place: Lisbon, Portugal.
Marital Status: married.
Professional Situation: Salesman, retired.
Family Structure: wife, one daughter and two grandsons.</td></tr>
<tr><td colspan="2">Backstory. Mr. Silva lives with his wife in Lisbon. He attended primary school but soon became a salesman for an important pharmaceutical company. He has a good house and combining both his salary and his wife's they can have a comfortable life. He is a very sociable person that usually goes out for a coffee with his wife or friends and therefore never feels lonely. Nevertheless, his family responsibilities are a limitation to a more active social life. He performs all his personal and housing activities and whenever he needs help just asks his wife. He usually also helps his daughter by taking care of his grandsons.</td></tr>
<tr><td colspan="2">Health information. Mr. Silva is considered healthy, in general, however, he is diabetic and has some memory disabilities.</td></tr>
<tr><td colspan="2">Technological knowledge. Mr. Silva has a landline phone and a mobile phone that he always uses to communicate with his family and friends. He also has a computer with Internet connection that he regularly uses.</td></tr>
<tr><td colspan="2">Fears and Frustrations. Mr. Silva's biggest fears are related to burglaries and fires. He is also slightly worried that his health may start to decline, especially when it comes to walking or climbing stairs.</td></tr>
<tr><td colspan="2">Motivation. Mr. Silva is an almost healthy person, but he is always trying to improve himself and maintain his health status good as long as possible. He is also very concerned with safety and would like to see some solutions to mitigate his fears, namely burglaries and fires, especially because he often has his little grandsons at home and wants them to be safe.</td></tr>
<tr><td colspan="2">Constraints. He is prepared to invest around 50 euros a month and wants services that are easy to use. He would like to have time to spend with his friends and family. Mr.</td></tr>
</table>

Silva needs to gauge his blood pressure three times per day. Currently, he uses a personal device to gauge the blood pressure and takes notes in a notebook. Sometimes, he just forgets to gauge the pressure. Also, he usually takes wrong annotations, which makes the process fully unreliable. Because he understands that his blood pressure is being monitored, but with faults, he declares that he has a high relevance to this situation. Mr. Silva also needs a security monitoring service to guarantee home safely because he pointed out that friends of the same age were recently assaulted, and he is very afraid pointing to a very high relevance to this circumstance.

We start by characterizing the life style of the customer Mr. Silva. His life style includes aspects of independent living, culture, religion, technology, among other data. For each parameter, the status and the personal relevance are associated. Mr. Silva's lifestyle characteristics are thus illustrated in Table 4.2. Note that this is not a comprehensive list of life style characteristics.

Table 4.2: Mr. Silva's Profile

Mr. Silva's Characteristics	Mr. Silva's Status	Mr. Silva's Relevance
Independent living	highly active	very important
Culture	not active	not important
Religion	active	not important
Social	not active	important
Technological	highly active	very important
Recreational	not active	very important
Financial	highly active	very important
Friendship	active	very important
Household	not active	very important
Community	not active	very important
Love	active	not important
Educational	active	not important
Professional	not active	not important
Health	active	very important
Family	active	very important

The care need *bloodPressure* can be associated with the goal *diseaseMaintenance* in the care need goals taxonomy (Figure 3.8), and the care need *homeSafety* can be associated with the goal *Safety*. After identifying the care needs, we proceed to obtain their relevance level (*rl*). For Mr. Silva, the *rl* for the care need *bloodPressure* is *high*, and *very high* for *homeSafety*. The *RQ* formalization is thus presented in Equation (15).

$$RQ = \left\{ \begin{array}{c} [JoãoSilva], \\ [(diseaseMaintenance, high), (Safety, very\ high)], \\ \left[\begin{array}{c} (\text{cost; soft; } \leq; 50), (\text{Technological usability; soft; =; high}), \\ (\text{specfic request; soft; =; medium}) \end{array} \right] \end{array} \right\} \quad (15)$$

4.2 ECE Personalization System: SCoPE Method

As mentioned above, it is assumed that, in general, the needs of a customer cannot be fully satisfied by a single service. Instead, a composition of various services is needed to (reasonably) cover all aspects (all care needs) of the customer's requirements.

In order to determine how well a given service can satisfy some part of the care needs of a specific customer, besides the intrinsic characteristics of the service, it is also necessary to consider the characteristics of the service provider. On the other hand, a set of needs typically require a number of services, each one covering only part of the needs. Therefore, an integrated care solution results from the composition of various "solution fragments", in which each fragment is a pair sp_{ij} = {service *i*, provider *j*}. Thus, it is necessary to determine how well each sp_{ij} matches or adheres to the user requirements. In other words, how well each particular "solution fragment" does its job.

Therefore, the proposed Service Personalization and Composition Environment (SCoPE) differs from classical approaches in the sense that first we assess the adherence of each potential "solution fragment" (sp_{ij}) to the user requirements, by making a detailed analysis of the involved characteristics (the personalization perspective), ranking all potential candidates, and only then the potential global solutions are ranked (compositions of promising "solution fragments"). Figure 4.1 illustrates this process, which consists of three main steps:

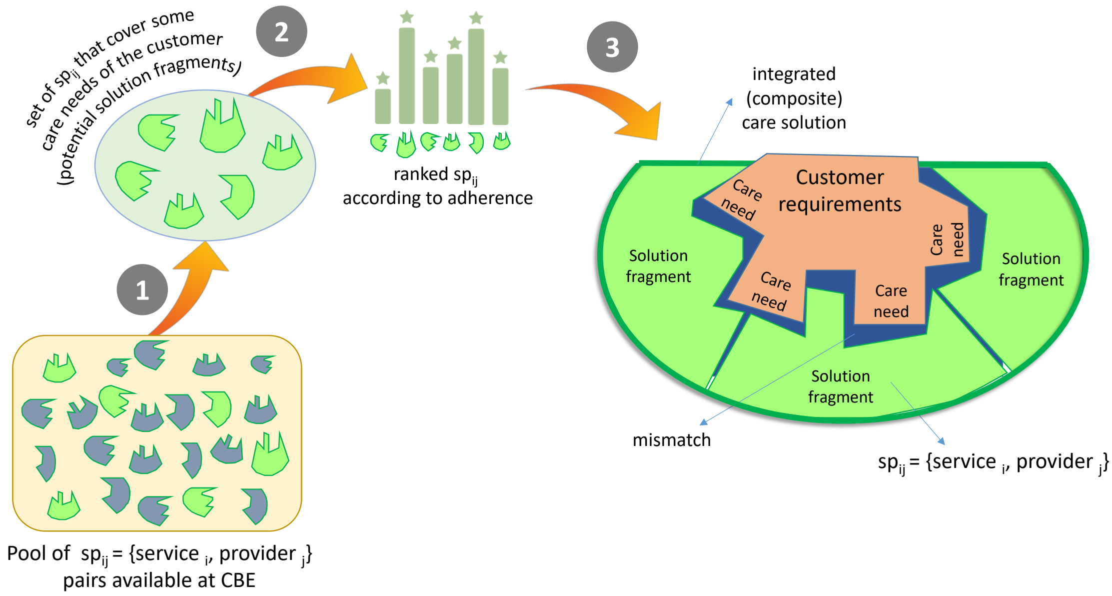


Figure 4.1: Steps in service selection and composition

Step: 1—Scope Filtering, the available services (and corresponding providers) that cover some of the customer's care needs are identified, resorting to the taxonomy of care need goals. From this list, we exclude those that are unsuitable due to geographical restrictions, special conditions, unavailable resources, and other hard constraints.

Step: 2—Adherence Calculation, which determines a compatibility index relating the customer profile, requirements and priorities to the providers' characteristics and care services features. The notion of *adherence* represents an aggregated view of fitness between the service and the need. The larger the *adherence* is, the more personalized the service is for a given customer's profile (and thus the smaller is the mismatch, dark area in Figure 4.1). Adherence is calculated for all sp_{ij} selected in the previous step.

Step: 3—Service Composition and Ranking, which rates and suggests compositions of services based on selected strategies. A composite care service represents a collection of related and integrated care services that provide a particular (complete) solution. The components of an integrated service may be provided by a number of service providers that must collaborate to offer such solution, and thus constitute a *virtual organization (VO)* for service provision. As such, the created virtual organization for delivering an integrated service is indirectly determined by the service selection and composition process. These steps are explained in the next sub-sessions.

4.2.1 Step: 1—Scope Filtering

This step is responsible for the matching of {service, provider} pairs that can meet the customer's request. The process is based on the goals of the taxonomy of care needs and customer's requirements. First, the {service, provider} pairs are selected based on *TX*goals (with penalties for pairs that do not meet the same level of selected *TX* goal). In the second stage, these pairs are filtered based on *hard* constraints (hard restrictions of customer, customer's limitations, service application restrictions, etc.).

For instance, if service delivery is not guaranteed in the customer's region, it is excluded, or if the service requires a specific resource which the customer does not have, this service is excluded. These are just some examples of hard restrictions for the exclusion process, but others can be considered, e.g., maximum cost, service provider preference, delivery time, etc.

At the end, a suitable set of $\boldsymbol{sp}_{ij}$ for the customer (and related care needs) is identified. Algorithm 4.1 shows a partial and simplified pseudo code formalism of *Scope Filtering*.

Algorithm 4.1: Scope Filtering Algorithm

```
function ScopeFiltering;
Input: ECE, cu, CA// ECE is the ecosystem, cu is the customer, CA the set of relevant
care needs to be processed
Output: SSE = {< cu, ca, se, weight >} // SSE is a set of tuples, in which cu is the
customer, ca is a care need of the customer cu, se is the service that can attend that care
need, and weight is the matching level of the service associated with the service
taxonomy
// Variables
var LSE; // a set containing services (SE)
var Lweight; // a weight to associate with the taxonomy matching
var Penalty: 0.1; // Penalty for higher-level matching, if the service covers a goal
bellow (chid node), it also covers the parent node but with a more restricted coverage
// Main
    foreach ca in CA do
      LSE ← null;
      foreach sp in ECE.SP do
            foreach se in sp.SE do
                  // provided services (SE) by specific service provider(sp)
                    Lweight ← 1;
                    More ← true;
                    Node1 ← ca.taxonomy.node;
                    Node2 ← searchNodeTaxonomy(se.taxonomy.node);
```

```
                        while True do
                                if (Node2 = null) or (Node1 = Node2) then
                                        break;
                                end
                                else
                                        Lweight ← Lweight − Penalty;
                                        Node2 ← Node2.parent;
                                end
                        end
                        if (Lweight <= 0) or (Node2 = null) then
                           // Did not have correspondence in the taxonomy
                                Lweight ← 0;
                        SSE ←+ < cu, ca, se, Lweight >;
                end
        end
end
```

Figure 4.2 illustrates the scenario previously presented for Mr. Silva. The main care needs of Mr. Silva are *homeSafety* (associated with the node *Safety*) and *bloodPressure* (associated with *diseaseMaintenance*). In this example, the identified services can be provided by either a unique service provider, or a VO. These aspects influence the adherence calculation of the suggested $\boldsymbol{sp}_{ij}$ fragments.

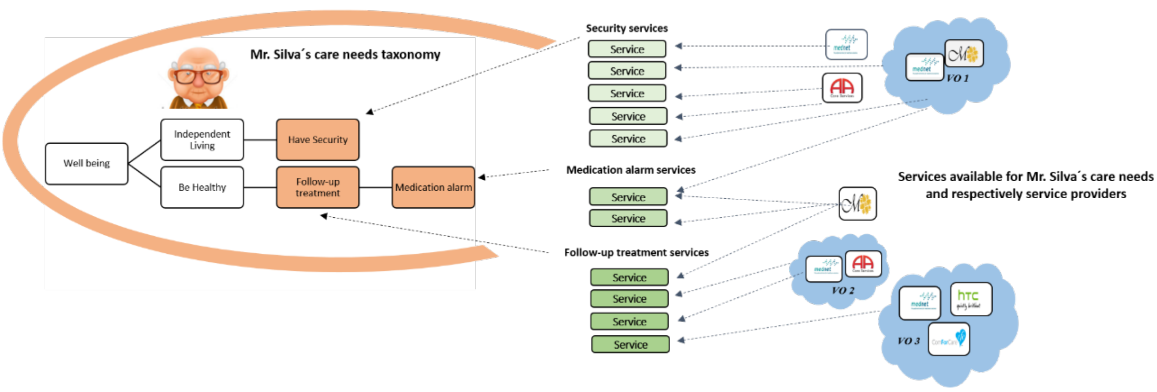


Figure 4.2: Mr. Silva's care needs sub-taxonomy and available sp_{ij} fragments

Let us imagine that based on the matching of care needs and services, the following services are found: s_1: Security_Guard Service; s_2: Remote_Monitoring Service; s_3: Agenda_Reminder Service;, s_4: Medication_Alert Service; s_5: Nursing_Robotic; and s_6: Home_Exercise Service. However, considering that s_5 (Nursing_Robotic) is not recommended for diabetic patients, which is the case of Mr. Silva, s_5 is removed from the list.

4.2.2 Step: 2—Adherence Calculation

Considering that *Adherence* represents a compatibility relation between the individual customer and a solution sp_{ij} fragment, it is calculated by estimating three coefficients: *Closeness* (CL); *Partial Adherence* (PA); and *Adherence* (ad). CL is represented by a multidimensional matrix of the proximity between customer's requests and the features of the {service, provider} pair fragment. PA is an intermediate computation that refines the closeness based on ponderation between customer's indicated relevance (RL) and service's coverage level (CO) for each care need. Finally, ad represents the resulting adherence index considering all care needs together.

Table 4.3 summarizes the adherence calculation process, including the purpose, inputs, and outputs for each sub-step.

Table 4.3. Adherence calculation process

Adherence Calculation Process Steps			Purpose	Input	Output
		Sub-step: 1 Closeness Calculation	Calculate the closeness vector ($\boldsymbol{CL}$) of each sp_{ij} fragment against the customer's requirements.	1. sp_{ij} fragments features 2. customer's requirements	*Closeness* vector ($\boldsymbol{CL}$) $= \{cl_1, cl_2, \dots, cl_n\}$
Repeated for each $\boldsymbol{sp_{ij}}$ ***fragment***	*Repeated for each care need*	Sub-step: 2 *Partial Adherence* calculation	Calculate the *Partial Adherence* coeficient*:* Combining the $\boldsymbol{CL}$ and the service coverage level ($\boldsymbol{CO}$) in relation to the customer's care need relevance.	1. $\boldsymbol{CL}$ 2. Customer's care need relevance ($\boldsymbol{RL}$) 3. Service Coverage Level regarding the care need ($\boldsymbol{CO}$)	*Partial adherence* coefficient ($\boldsymbol{PA}$)
		Sub-step: 3 *Adherence* calculation	Calculate the *Adherence* combining all care needs together	1. $\boldsymbol{PA}$	*Adherence* coefficient ($\boldsymbol{ad}$)

The three sub-steps should be repeated for each sp_{ij} fragment resulted from the *Scope Filtering* step. Let's see these sub-steps in more details:

Sub-step 1—CL calculation. Since we aim at service personalization and adaptability for each customer, a particular consideration is put on comparing solutions with the customer's profile and requests. To find the solution that has the best adherence, the assessment it based on each customer's requirement.

$\boldsymbol{CL}$ considers the *distance* between customer's requests and the related features of $\boldsymbol{sp_{ij}}$. The larger the distance is, the smaller $\boldsymbol{CL}$ is. As each customer has different needs/requests, the same service and provider fragment can have different closeness to different customers.

Currently, $\boldsymbol{CL}$ calculation method considers the following situations: (a) when the customer's request and the features of {service, provider} fragment are quantitatively expressed (crisp); (b) when the customer's request and the features of the {service, provider} fragment are qualitatively expressed (fuzzy); and (c) when the customer's request is not previously planned in the ECE.

The initial classification of the {service, provider} pair features can be given by the ECE stakeholders (e.g., service provider members, customers, or ECE manager), by professionals in elderly care, or derived from statistical data. Some values might not be available yet (e.g., the service is not rated yet because it is new in the ECE) or not necessary for the customer (e.g., the customer has no constraints).

It is considered that all {service, provider} fragments that offer equal or better features in comparison with customer's requests have a cl_i corresponding to the optimal solution (cl_i= 1). For the other cases, we calculate the *closeness* based on the distance of customer's requirements to {service, provider} fragment features. Following the situations (a), (b), and (c) above, the adopted *CL* calculation is done by:

$$\boldsymbol{CL} = \left\{ \begin{array}{ll} \boldsymbol{cl_{crisp}} & | \; if\ requirements\ are\ expresed\ in\ crisp\ value \\ \boldsymbol{cl_{fuzzy}} & | \; if\ requirements\ are\ expresed\ in\ fuzzy\ scale \\ \boldsymbol{cl_{flex}} & | \; if\ requirements\ are\ presuppose\ flexibility \end{array} \right\} \quad (16)$$

Calculation for situation (a)—a crisp comparison:

$$\boldsymbol{cl_{crisp}} = \frac{customer's\ requeriment}{\{service,\ provider\}\ fragment\ \ feature} \quad (17)$$

For instance, if the customer wishes a maximum cost of 50 €, and the fragment's price is 60 €, then cl_{crisp} is "0.83".

Calculation for situation (b)—a fuzzy comparison:

$$\boldsymbol{cl_{fuzzy}} = 1 - d(£_1, £_2). \tag{18}$$

The adopted method for *distance* calculation in this situation is based on fuzzy linguistic variables. Trapezoidal fuzzy numbers are more appropriate since the degree of uncertainty in the variable values is high (Zimmermann, 1996). Considering $£_i$ as a trapezoidal fuzzy number, defined by (a_i, b_i, c_i, d_i), where a_i, b_i, c_i and $d_i \in [0,1]$, the distance between two numbers $\mathbf{£_1}$and $\mathbf{£_2}$ is given by (Zimmermann, 1996):

$$\boldsymbol{d}(£_1, £_2) = \frac{1}{8}[|(a_1 - a_2)| + |(b_1 - b_2)| + |(c_1 - c_2)| + |(d_1 - d_2)|]. \tag{19}$$

For instance, if the customer's level of technological knowledge is *low* and the service *usability* is *medium*, two fuzzy trapezoidal numbers with linguist terms Low ($£_1$) and Medium ($£_2$) are illustrated in Figure 4.3. The *distance* between them (from Equation (18)) has the value "0.11", and the corresponding $\boldsymbol{cl_{fuzzy}}$ value is "0.89" (from Equation (19)).

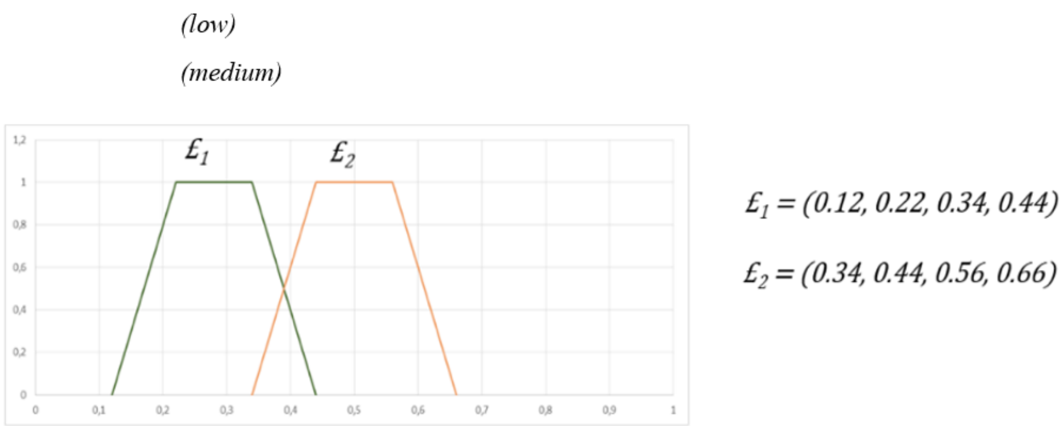


Figure 4.3: Fuzzy trapezoidal number illustration

Calculation for situation (c)—based on service provider flexibility:

At an individual level, flexibility is the ability to incorporate variations in the execution of the care service within a process definition by customer request. For instance, modification of service delivery in response to a customer desire. As such, the specific request is represented by parameters characterizing the flexibility level e.g., delivery conditions, business process, service features, etc. We consider different flexibility zones, for instance, the service provider can be *very flexible* for delivery resources, but *not very flexible* to change the business process.

Table 4.4 shows a possible scale of flexibility degrees. If the service provider has a flexibility level *very flexible*, $\boldsymbol{cl_{flex}}$ has value "1".

Table 4.4: Provider flexibility scale

Flexibility Degree	Flexibility Level	Description
1	*Very flexible*	Always or almost always adapts to the customer's request.
0.75	*Flexible*	Usually adapts to the customer's request.
0.5	*Moderately flexible*	Sometimes adapts to the customer's request.
0.25	*Not very flexible*	Seldom adapts to the customer's request.
0	*Not flexible*	Never adapts to the customer's request.

For instance, if a customer requests a car with a specific colour for delivering a service (e.g., red car), the request has a *very high* exigency level (corresponding to a *very flexible* service provider), and the service provider has a *Moderately flexible* flexibility level; thus, the corresponding $\boldsymbol{cl_{flex}}$ is "0.5".

Algorithm 4.2 shows a partial closeness calculation algorithm in a simplified pseudo code formalism.

Algorithm 4.2: Closeness Adherence Algorithm

```
function Closeness;
// ECE is the ecosystem, cu is the customer, ca is a care need, and SEW = {< ca_i, se, w
>}, where ca_i is the current care need, se a service that attends this care, and w is the
weight of the service associated with the taxonomy (calculated in Algorithm 1),and
req is customer's requirements
Input : ECE, cu, SEW, RE
// The output is a set containing tuples composed of a requirement req, a service se,
and the adherence ad ∈[0, 1] of the service se to the requirement req
Output: CL[n] = {< se, req, ad >}
// Variables
var n=req ; // number of requirements
var t;// a vector
// Main
while SEW.hasTuples do
        t ← SEW.nextTuple();
        i ←1;
        foreach req in t.ca.getRequirements do
                foreach fea in t.se.getFeatures do
                        if (req.id = fea.id) then
                          // simplified function
                                switch req.type do
```

```
                case FUZZY do
                    // closeness calculation based on fuzzy
                    function, distance between trapezoidal
                    numbers
                    CL[i] ←+ < se, req, doTrapezoidal(se, req, f e)
                >;
                    break;
                case CRISP do
                    // closeness calculation based on crisp
                function, relation between customer requirements
                and service features
                    CL[i] ←+ < se, req, doCrisp(se, req, fe)) >;
                    break
                otherwise do
                 // closeness calculation based on provider
                 flexibility level
                    CL[i] ←+ < se, req, doFlexibility(se, req, f e)
                >;
                end
            end
            i++
        end
    end
end
```

At the end, a *closeness* vector $CL_m = \{cl_1, cl_2, \ldots, cl_n\}$ is calculated, where the number of elements (*n*) corresponds to the number of requirements. For instance, if we consider the previous scenario examples, $CL_1 = \{0.83, 0.89, 0.5\}$ is obtained.

Sub-step 2—Weighted PA vector calculation. For each care need *m*, the $G(cl_m)$ coefficient is the average of *closeness* *CL* vector elements given by:

$$G(cl_m) = \frac{\sum_{x=1}^{n} cl_x}{n}. \tag{20}$$

PA combines the *G(cl)* coefficient and compares the service coverage level (CO) in relation to the customer's care needs relevance (RL). For each care need *m*, a corresponding pa_m is calculated. The CO is defined when the service provider registers a service in the ECE and it is associated with a care need. The *RL* is defined by the customer when the care need is requested. CO and RL coefficients are expressed in a fuzzy scale. However, they are often checked and adjusted at any time if necessary. The condition presented below gives the *PA* calculation.

$$pa_m = \begin{cases} G(cl_m) \cdot [1 + distance(CO_m, RL_m)] & if\ cov_m \geq rl_m \\ G(cl_m) \cdot [1 - distance(CO_m, RL_m)] & otherwise \end{cases} \quad (21)$$

where *distance* represents the distance between RL and CO (given by Equation (18)) related to care need m.

Our partial adherence calculation method is shown in Algorithm 4.3 using a simplified pseudo code formalism.

Algorithm 4.3: ***Partial Adherence Algorithm***

```
function PartialAdherence;
// G(CL) is the average closeness considering all requirements of each care need, CO
is the service coverage level in relation to the customers care need relevance RL
Input: G(CL), CO, RL
// The output is a set containing tuples composed of a requirement req, a sevice se,
and the adherence ad ∈[0, 1] of the service se to the requirement req
Output: PA
// Main
var m:0.0; // a number of customer's care needs
foreach ca in cu.ca do
        if (se.CO >= ca.RL) then
                PA[m] ← G(CL) ∗ (1 + distance(se.CO, ca.RL))
                else
                        PA[m] ← G(CL) ∗ (1 − distance(se.CO, ca.RL))
                end
        m++
end
```

At the end, the vector $PA = \{pa_1, pa_2, \dots, pa_m\}$ is calculated, where the number of elements *(m)* correspond to the number of customer's care needs.

For instance, considering $\boldsymbol{sp}_{ij}$ fragment associated to two care needs with $co_1 = veryhigh$ and $co_2 = medium$, and with a relevance level $rl_1 = high$ and $rl_2 = veryhigh$ and $CL = \{0.83, 0.89\}$, the corresponding pa_1 is 0.92 (for the care need *bloodPressure*), and pa_2 is 0.69 (for the care need *homeSafety*), thus $PA_{sp_{ij}} = \{0.92, 0.69\}$.

Sub-step 3—Adherence (ad) Calculation. *ad* represents the "global" adherence covering all care needs and is given by:

$$\boldsymbol{ad} = \frac{1}{m} \sum_{x=1}^{m} pa_x. \quad (22)$$

An example is shown in Table 4.5.

Table 4.5: Illustrative example of *Solution* combining with *pa* and *ad*

Solution	pa_1	pa_2	ad
sp_{ij}	0.92	0.69	0.81

At the end, a solution's matrix is presented. Table 4.6 illustrates the matrix structure: the first column identifies the solution fragment (sp_{ij}), the next columns include the partial adherence pa_m for each care need m, the next column is "global" adherence *ad* for the current sp_{ij} solution. Complementing the found solutions and to help in the choice of the customer, the algorithm further adds columns of the price of solution (*cost*) and the relation between the adherence and the corresponding price of solution (*cost-benefit ratio*).

Table 4.6: Solution's matrix structure

Solution	pa_1	pa_2	…	pa_m	ad	Cost	Cost-Benefit Ratio
sp_{11}	$pa_{ca_1}(sp_{11})$	$pa_{ca_2}(sp_{11})$	…	$pa_{ca_m}(sp_{11})$	$ad\ (sp_{11})$	$cost\ (sp_{11})$	$\frac{ad\ (sp_{11})}{cost\ (sp_{11})}$
sp_{22}	$pa_{ca_1}(sp_{22})$	$pa_{ca_2}(sp_{22})$	…	$pa_{ca_m}(sp_{22})$	$ad\ (sp_{22})$	$cost\ (sp_{22})$	$\frac{ad\ (sp_{22})}{cost\ (sp_{22})}$
sp_{23}	$pa_{ca_1}(sp_{23})$	$pa_{ca_2}(sp_{23})$	…	$pa_{ca_m}(sp_{23})$	$ad\ (sp_{23})$	$cost(sp_{23})$	$\frac{ad\ (sp_{23})}{cost\ (sp_{23})}$
…	…	…	…	…	…	…	…
sp_{ij}	$pa_{ca_1}(sp_{ij})$	$pa_{ca_2}(sp_{ij})$	…	$pa_{ca_m}(sp_{ij})$	$ad\ (sp_{ij})$	$cost\ (sp_{ij})$	$\frac{ad\ (sp_{ij})}{cost\ (sp_{ij})}$

Let us exemplify the Adherence Calculation process for Mr. Silva's scenario:

Sub-step 1—CL calculation for Mr. Silva. Closeness is calculated assuming that the profile, care needs, care needs relevance, customer requirements and promising solution fragment (sp_{ij}), are already identified or characterized.

Having this as background, let us suppose that Mr. Silva selected three requirements for classifying a solution: *medium* use facility; delivery time within 24 h; and the possibility of service suspension on holidays without cost. For Mr.

Silva, the first criterion is identified by *usability level*, corresponding to *situation (b)* in cl_{fuzzy} calculation. The second criterion, *delivery time* represents a *situation (a)*, and the last criterion, *suspension on holiday* corresponds to a *situation (c)* of *business process flexibility level* of service provider.

Taking into account the selected requirements, the first one re_1 *(usability*, is "*medium*", and if we consider that the solution sp_{11} is "*low*", by using balanced linguistic modeling (Chen & Chen, 2003) through the linguistic term and its associated trapezoidal fuzzy number, we have two fuzzy trapezoidal numbers with linguist term *Low* ($£_1$) and *Medium* ($£_2$). Thus cl_{fuzzy} (calculated by Equation (18)) represents here $1 - 1d(£_1, £_2)$, $\boldsymbol{cl_{fuzzy}}$ is 0.89.

For the second requirement, re_2: *time delivery*, the sp_{11} is available in two hours, so the sp_{11} features are better than the customer's request (24 h), thus cl_{crisp} corresponds to "1". The last requirement involves business process changes following a *very high* exigency level (corresponding to a *very flexible* solution). The sp_{11} fragment has a *moderate* flexibility level, thus the corresponding closeness through the linguistics terms is 0.5. For each {service, provider} fragment and set of requirements, a step-by-step calculation is performed and the corresponding closeness vector *CL*, for Mr. Silva and sp_{11} fragment, is $CL = \{0.89, 1, 0.5\}$, and the corresponding $G(cl_m)$ is 0.797.

Sub-step 2—Partial Adherence (PA) calculation. Considering the two care needs of Mr. Silva: *bloodPressure* and *homeSafety*, and the service coverage level (CO) coefficient assigned in the care needs taxonomy to sp_{11} *fragment* of $CO = \{co_1, co_2\} = \{very\ high, low\}$, the *PA* associated with Mr. Silva's care needs is the following (based on Equation (15)), $pa_1 = 0.885$ and $pa_2 = 0.622$, thus: $PA_{sp_{11}} = \{0.885, 0.622\}$.

Sub-step 3—Adherence calculation. After that all fragments got a PA, the Solution's matrix is built. Table 4.7 shows the matrix for Mr. Silva. Like for solution sp_{11}, exemplified above, a similar process is applied to all sp_{ij} rows.

Table 4.7: Mr. Silva's Solution's matrix

Fragment	pa_1 (ca_1 = *Blood Pressure*)	pa_2 (ca_2 = *Home Safety*)	*ad*	Cost	Cost-Benefit Ratio (%)
sp_{11}	0.885	0.622	0.75	100 €	0.75
sp_{21}	0.184	0.782	0.48	30 €	1.60
sp_{22}	0.000	0.927	0.46	40 €	1.15
sp_{33}	0.345	0.451	0.39	85 €	0.46
sp_{41}	0.767	0.000	0.38	200 €	0.19
sp_{64}	0.639	0.791	0.71	75 €	0.95

4.2.3 Step: 3—Service Composition and Ranking

Considering Mr. Silva's scenario, the relevance level indicated for *bloodPressure* and *homeSafety* are *high* and *very high*, respectively. The first process excludes services that do not cover the needs with the desired relevance. Considering the mapping of Table 4.**6** and the *high* relevance indicated for *bloodPressure* care need, we only consider services with *high* or *very high* adherence level, thus the s_2 (sp_{21} and sp_{22} fragments) and s_3 (sp_{33} fragment) services are eliminated. Similarly, for the *homeSafety* care need, services s_1 (sp_{11} fragment), s_3, and s_4 (sp_{41} fragment) are discarded. Therefore, Table 4.**8** shows the remaining {service, provider} pairs for Mr. Silva's care needs, with the corresponding pa values. An example of cost values is also included, to illustrate the next steps.

Table 4.8: Selected solution fragments for Mr. Silva's care needs

To Care Need bloodPressure			*To Care Need homeSafety*		
Available Solutions	*pa*	Cost	Available Solutions	*pa*	Cost
sp_{11}	0.885	100 €	sp_{21}	0.782	30 €
sp_{41}	0.767	200 €	sp_{22}	0.927	40 €
sp_{64}	0.639	75 €	sp_{64}	0.791	75 €

The service composition process can then proceed using this group of sp_{ij} fragments, which have a reasonable adherence level. Various alternative composition methods are considered. For instance, a method based on the greedy constructive strategy (Rothlauf, 2011), which composes services based on maximization of values. The greedy strategy builds the solution "care need by care need", i.e., for each care need, a choice is made regarding the sp_{ij} that looks best for that care need (better pa). In situations that two services have the same *pa* value for the same care need, both are considered as greedy options, and more than one integrated solution can be found. Considering the number of care needs is m, then the services set will have at most m services.

Another possible method seeks to minimize the number of service providers. This can be attempted by minimizing the number of included services, which will probably reduce the number of service providers, and increase the chances of better integration for service delivery.

Since having several service providers may decrease delivery disruption risks, a third method can be adopted to consider this goal.

Other methods can be considered depending on the ECE current goals or plans (Jula et al., 2014). Table 4.**9** summarizes some composition strategies and their corresponding benefits. In the above discussion, service *adherence* is the leading criterion for service ranking. However, other constraints and parameters can be used. For instance, the relation between service cost and adherence, number of services, the number of involved providers, ECE management strategies or decisions (personalized choice), historical information about service performance, service reputation, etc. The customer interaction is primordial at this stage of negotiation and solution selection.

Table 4.9: Some composition methods

Composition Method	Solution Index	Expected Benefit
$Method_1$	Adherence maximization	Better service personalization
$Method_2$	Services minimization	Better service integration, less interoperability problems
$Method_3$	Providers minimization	Better integration and cost decrease
$Method_4$	Balanced Number of Providers	Minimization of service delivery disruption risks
…	…	…
$Method_n$	To define	To define

Algorithm 4.4 shows a partial service composition and ranking algorithm in a simplified pseudo code formalism.

Algorithm 4.4: Service Composition and Ranking Algorithm

```
function ServiceComposition;
// Solution is a vector of services that attend the customer's request
```

```
Input: CA, cu, PA, cost
// The output is a set containing tuples composed of a Solution, a solution cost, the
adherence ad ∈ [0, 1] of the Solution to the customer cu, and the ranking based on the
relation between ad and cost
Output: SolutionsRanking

Procedure AdherenceMaximization;
var Solution1; // a vector of services that cover the care needs
var ad:0.0; // the solution adherence
var x: 0.0; // an auxiliary variable
var m; // number of customer´s care needs
var n:0.0; // number of solutions in this strategy (adherence maximization)
// Main
foreach ca in cu.CA do
        Solution1 ← null;
        foreach se in ca.se do
                n++;
                if (PA[n]) > x then
                        x ← se.pa;
                        Solution1[n] ←+ < se.ca >;
                end
            ad.solution1[n] ← (x);
        end
        ad.solution1[n] ← average;
end

Procedure ServiceMinimization;
var Solution2; // a set of services that cover the care needs
var ad:0.0; // the solution adherence
var n:0.0; // number of solutions in this strategy (service minimization)
// Main
foreach ca in cu.CA do
        Solution2 ← null;
        foreach se in ca.se do
        n++;
        if se is the same than (ca++).se then
            ad.Solution2[n] ← se.pa;
            Solution2[n] ←+ < se.ca >;
        end
end
        ad.solution2[n] ← average;
end

Procedure ProviderMinimization;
// strategy for minimization of provider's number
end

Procedure DefinedStrategy;
// new strategy
end
```

Table 4.10 shows some example solutions for Mr. Silva's scenario. The first solution has an ad value of 0.906, the highest adherence to the needs. A single fragment (sp_{64}) can satisfactorily attend all Mr. Silva's care needs (*solution 2)* with ad of 0.715. Next solutions are based on service provider minimization and have a ad of 0.755 and 0.774.

If we consider the cost, then the solution's matrix can be expanded to include another ranking that combines ad and *cost*. At this stage, the human-in-the-loop process starts and ECE broker interacts with Mr. Silva, to discuss opportunities, advantages, and disadvantages of the various solutions and make a final decision.

Table 4.10: Solution's matrix for Mr. Silva' scenario

Method	Solutions	*To Care Need Blood Pressure*	*To Care Need Home Safety*	ad	Cost	Cost-Benefit Ratio (%)
Method_1	*Solution 1*	sp_{11}	sp_{22}	0.906	140 €	0.647
Method_2	*Solution 2*	sp_{64}		0.715	75 €	0.953
Method_3	*Solution 3*	sp_{11}	sp_{21}	0.755	130 €	0.581
	Solution 4	sp_{41}	sp_{21}	0.774	230 €	0.337

4.3 Summary

In this chapter, we presented the ECE_{PS} that proposes the SCoPE method to support the process of composing and personalizing services in a collaborative network environment for elderly care. This method is based on three main steps: (a) scope filtering—responsible for matching and excluding or accepting {service, provider} pairs based on the care needs taxonomy; (b) adherence calculation—resulting the first rating of {service, provider} pairs based on a multidimensional matrix representing the adherence to each specific customer; and (c) service composition and solution ranking—using a number of strategies for service composition, resulting in a ranked list of potential solutions. In this context, SCoPE includes:

- A new service selection paradigm based on solution adherence to the customer needs and specificities, making possible to attend personal requirements through soft criteria.
- Possibility of integration of services of diverse areas and types covering several care needs.

- Adherence calculation respecting personal characteristics (e.g., cultural, technological, social, etc.) based on care needs and criteria relevance.
- Service composition based on an *adherence* coefficient, offering tailored services to each senior context and his/her life-style, strengthening service personalization.

Partial algorithms for SCoPE implementation are presented and the method is applied to an illustrative scenario in which an elderly person depends on composed care services to improve his quality of life. The illustrative scenario application shows the viability and facility of building models on top of the ECE framework and demonstrates the appropriateness of the modelling approaches in terms of fit-for-purpose and usefulness.

5

Service Evolution System: The SEvol Method

This section starts by presenting an adaptive system´s approach for service evolution in the scope of ECE. Then, an evolutionary and adaptive system and the associated SEvol method based on MAPE-k control loop structure are described. This method encompasses four elements: Monitor, Analyzer, Planner, and Executor. Then, the specific model for Service Evolution is introduced and the solution evolution loop within ECE is detailed. Next, a workflow diagram is presented considering the main ECE´s processes and their interactions demonstrating the ECE environments and ECE phases of execution. Finally, a summary closes this chapter.

5.1Evolutionary and Adaptive System

Adaptive and self-adaptive systems are a broad area of research with significant recent advances (De Lemos et al., 2013; Salehie & Tahvildari, 2009). These systems are characterized by having the capability of modifying their behavior and/or structure in response to their perception of the context and the system itself, and their requirements (Laddaga & Robertson, 2004). The term "self" represents the completeness of a system, mostly implemented in several layers, while the context encompasses everything in the operating environment that affects the system's properties and its behaviors, such as end-user input, external hardware devices, and sensors, or program instrumentation (Oreizy et al., 1999). In summary, an adaptive system is "required to monitor itself and its context, detect significant changes, decide how to react, and act to execute such decisions" (De Lemos et al., 2013; Salehie & Tahvildari, 2009).

The critical point in a self-adaptive system is that its life-cycle should not be interrupted after its development and initial set up. Similarly, service operation should continue after deployment while evaluating the system and responding to changes at all time. In this sense, self-adaptive systems are realised as closed-loop systems with feedback loop (Salehie & Tahvildari, 2009). During the adaptive process, it is possible to perform (if necessary) a human-in-the-loop action and the process continues after customer´s feedback. In this situation, the adaptive system has a semi-dynamic adaptation.

Semi-dynamic adaptation is classified into two main paradigms that determine the range of possible states a system considers during the decision process (Macedo, 2011; Shelton et al., 2003): dynamic behavior adaptation, and dynamic reconfiguration.

In the case of dynamic behavior adaptation a system recognizes new environment conditions not envisioned during its initial development and then control and order are emergent rather than predetermined. In the case of dynamic reconfiguration it encompasses possible variants of behavior that are somehow predefined before execution. During execution, current state, environment, and context are evaluated, and the most appropriate behavior variant is selected.

Some architecture-based adaptation frameworks have been proposed and developed over the years. They represent either academic or industry initiatives to address issues on the self-* properties and the adaptation process itself (Brun et al., 2009; De Lemos et al., 2013). Developing adaptive technologies and frameworks is beyond the scope of this work, hence existing adaptive approaches are considered to support our approach.

As such, the proposed evolution system is based on the MAPE-K control loop structure (Arcaini et al., 2015; IBM, 2006). MAPE-K is a consolidated model for system adaptation, including socio-technical systems (Dalpiaz, 2011), such as collaborative networks. This control loop traditionally covers four elements: *Monitor*, *Analyze*, *Plan* and *Execute*. "*Monitor*" collects the details from the managed resources (e.g., sensors data, customer´s information, configuration property settings, etc.). The monitor function aggregates, correlates and filters (besides normalizing) these details until it determines a symptom that needs to be analysed. "A*nalyze*" performs (complex) data analysis and reasoning on the symptoms provided by the monitor function. If changes are required, a change request is logically passed to the plan function. The element "*Plan*" structures the actions needed to achieve goals and creates or selects a process to enact a desired modification in the managed resource. Finally, "E*xecute*" changes the behavior of the managed resource using effectors based on the actions recommended by the plan function.

5.2Evolution System: the SEvol Method

In the elderly care ecosystem domain, and for each new context change, the proposed ECE Evolution System analyses the situation (in collaboration with the relevant stakeholders) and adapts the service to fit that new context. In other words, the Service Evolution (SEvol) method supports the solution evolution to cope with the new life stage. Under this perspective, the notion of evolutionary service (Baldissera & Camarinha-Matos, 2018b; Brown et al., 2002; Hong et al., 2009; Marcos-Pablos & García-Peñalvo, 2019; O'Grady et al., 2010) means that the provided service is adapted to the senior's needs, and to new changes that affect the senior´s life context.

Following MAPE-K, the SEvol method is based on a control loop composed of four main stages: (i) monitoring events that occur in the surrounding physical and social context (i.e., both context changes and messages exchanged between stakeholders); (ii) analyzing monitored data against solution requirements to identify need of adaptation; (iii) devising an evolution strategy that reconciles current solution with a new customer´s context; and (iv) enacting such strategy while minimizing disturbances caused by suggested solutions. These stages are identified in the i* rationale strategic model (see Figure 5.1) that provides an intentional description in terms of process elements and the rationales behind them (Yu & Mylopoulos, 1995).

In the i* glossary (Yu & Mylopoulos, 1995), <u>actors</u> are active entities that carry out actions to achieve goals by exercising their know-how. When an actor wants to accomplish some specific <u>task</u>, performed in a particular way, a description of the specifics of the task may be described by decomposing the task into further sub-elements (sub-tasks). <u>Goals</u> represents an intentional desire of an actor. Finally, <u>resources</u> are entities, physical or informational, provided by the actors.

The main actor is the *Evolution System* (A-04 in Figure 5.1) that is supported by additional elements of the model: *Context sensor* (A-01), *Agent* (A-02), and *Contextual actuator* (A-03). In more detail:

- *Context sensor* (A-01) is seen as a computational entity (hardware and software) providing raw data about the elderly environment. For instance, a bracelet that determines the current location of the customer or other stakeholders (e.g., who deliver/execute the care service), the sensor that determines the temperature and humidity levels in specific places, the smart communicator's automatic incoming/outgoing calls, etc.

- *Agent* (A-02) represents each of the actors who need to be monitored to ensure that they deliver according to their role in the ecosystem and send feedback about their acts. These agents may represent a senior, her/his guardian or caregiver, the coordinator of the virtual organization (who manages the care service delivery for this senior), a service provider (which is part of a VO), etc. Agents are linked with the *Evolution System* (A-04) through inputs provision to identify a new request or through choices made in the human interaction. For instance, a substitution of a resource may be solicited by a service provider.

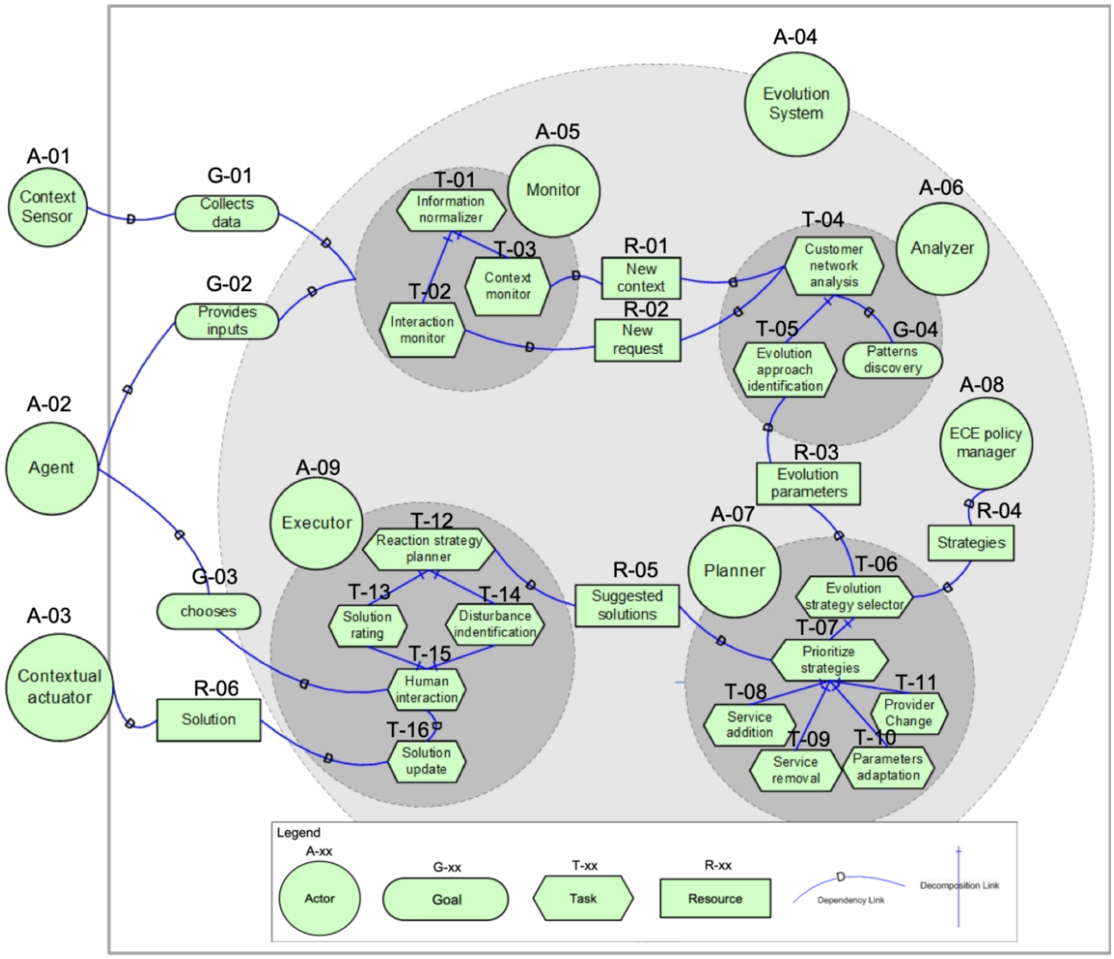


Figure 5.1: Adapted i* Rationale Strategic Model for the Evolution System Loop in ECE

- *Context actuator* (A-03) represents any stakeholder in the ecosystem that can receive commands and act. For instance, technological devices (door openers, automated air conditioning control, alarms, remote light switches, automatic 112 callers, etc.) or persons (who delivery the service, a relative, etc.). Notice that agents and context actuators are commonly exclusive actors: while agents are autonomous, heterogeneous, and uncontrollable, context actuators are passive and controllable (except when they are people).

- *Evolution System* (A-04) provides the self-adaptation capabilities of our model. This actor is split into four sub-actors:

(a) Sub-actor *Monitor* (A-05) receives the information from agents (*Agent* (A-02)) and sensors (*Context Sensor* (A-01)). The inputs from the agents can be of several origins, for instance, from the customer and his/her family and guardian, or from the ECE, mainly originated in the Virtual Organization coordination, ECE management, or service provider. The inputs from sensors represent data about the elderly environment, for instance, information about senior's sleep analysis. Examples of outcomes are: (i) the identified new care need, (ii) indication that a care need is no longer present, and (iii) indication that a service changed the delivery parameters.

(b) Sub-actor *Analyzer* (A-06) receives from *Monitor* (A-05) information about the current elderly living context (*New context* (R-01) or *New request* (R-02)) and observes the pattern identifying the solution parameters that need to evolve.

(c) Sub-actor *Planner* (A-07) selects evolution strategies to be adopted by the ECE policy manager (A-08), and ranks suggested solutions. The proposed solution evolution approach in ECE is based on composition (or decomposition) of the current solution (*Service addition* (T-08) or *Service removal* (T-09)); on solution parameters change (*Parameters adaptation* (T-10)), for instance, delivery conditions; or the change of the entity responsible for the care service delivery (*Provider change* (T-11)).

(d) Sub-actor *Executor* (A-09) changes the behavior of the managed resource using effectors based on the actions recommended by the *Planner* (A-07). Notice that evolution should not be considered a new personalization since it does not seek the better possible results from scratch, but instead seeks a satisfactory solution with the least possible disturbance to the customer (that is already used to the specific characteristics of current solution).

More details about these four sub-actors are detailed in the following subsections.

5.2.1 Sub-actor *Monitor*

The *Monitor*'s (A-05) purpose is to identify relevant changes in the physical and social context, notifying the *Analyzer* actor (A-06). To collect inputs, the *Monitor* relies on context sensors and agents. Distinct tasks are needed to achieve the *Monitor*'s goal:

The task *Information normalizer* (T-01) initiates the monitoring function, taking its input from sensors or agents. The collected data and provided inputs are normalized to a "common language" that expresses the information on a context model (see Figure 5.2).

The *Collects data* (G-01) and P*rovides inputs* (G-02) are required by the Monitor´s tasks: *Interaction monitor* (T-02) and *Context monitor* (T-03).

- The *Interaction monitor* (T-02) processes the status of existing non-standard data and exposes it through *New request* (R-02). For instance, a service provider will no longer deliver a specific service, or the customer wants to lower the price of a solution.
- The *Context monitor* (T-03) computes information related to context and establishes *New context* (R-01). For example, if the customer has a medical appointment and her/his location is not moving, this information is sent (he/she did visit the doctor), or he/she is five days without leaving home, not participating in routine meetings (indicating signs of isolation, a possible new care need.)

Figure 5.2 sketches how the *Information normalizer* (T-01) works. Some inputs are sent in different formats: an XML file from the smart t-shirt, binary raw data from the door, CSV (comma-separated values) data from the thermometer, change of request from the customer activating (or disabling) care needs, customer changed constraints, and a service provider removing a limitation or adding an application suggestion.

Normalization requires the definition of a translation schema for each raw data format. If the task sources provide data in standard formats (e.g., XML file from the smart t-shirt), transformation schemes can be defined using a transformation language (e.g., XSLT – eXtensible Stylesheet Language Transformation).

If the house entrance door is closed (e.g. door.status = closed) and an event such as open(door, time i) happens, the *Context Monitor* (T-03) converts these data in terms of a shared context environment changing the status of the entrance door to open (door.status = open) – representing a *New context* (R-01): "door1.opened". A the other hand, if the customer identifies a new need (e.g. need of transportation), the *Iteration monitor* (T-02) processes events related to context and exposes this requirement, representing a *New request* (R-02): "node35.active=transportation".

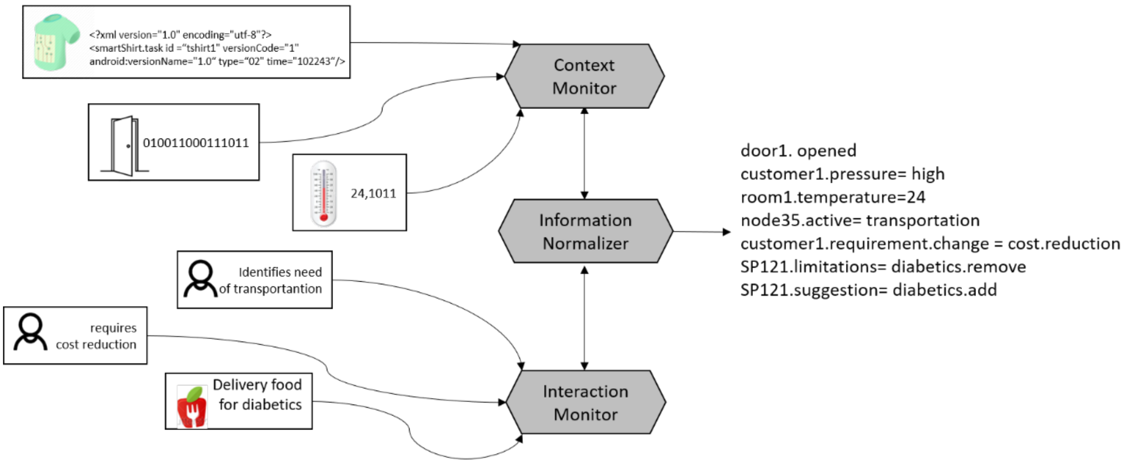


Figure 5.2: Overview of *Information normalizer* task

5.2.2 Sub-actor *Analyzer*

Sub-actor *Analyzer* (A-06) is responsible for checking current information about the Evolution System (A-04) collected by the *Monitor*.

The role of requirements to the *Customer network analysis* (T-04) is to specify what should happen and hold: which goals should/can/cannot be achieved by certain agents, which plans they can/cannot execute in different contexts, the domain assumptions that should not be violated. On the other hand, the richer the requirements models are, the more accurate the diagnosis will be. However, the granularity of agents is constrained by technological and pragmatic aspects. Detecting if the senior is lying on the bed is readily feasible (e.g. through pressure sensors), while detecting if the senior is taking the medicine the correct way is far more complex.

The goal *Patterns discovery* (G-04) identifies and sets patterns of something routine that was not previously declared. It can declare patterns from the provider or stakeholders (sensors, caregivers, etc.). The task *Evolution approach identification* (T-05) observes the patterns of customer behavior and indicates evolution parameters according to their priority level, and provides the resource *Evolution parameters* (R-03) to sub-actor *Planner* (A-07).

5.2.3 Sub-actor *Planner*

Planner (A-07) analyzes *Evolution parameters* (R-03) selecting the evolution strategies to this context serving as a system interface with *ECE policy manager* (A-07) that handles policies defined by ECE managers. *Evolution strategy selector* (T-06) receives the *Strategies* (R-04) from *ECE policy manager* (A-07) and prioritizes these solutions considering the ECE policies and goals (subtask *Prioritize strategies* (T-07)). The suggested strategies for solution evolution are based on the following tasks: *Service addition* (T-08) , *Service removal* (T-09), *Parameters adaptation* (T-10), and *Provider Change* (T-11). In the end, a resource *Suggested solutions* (R-05) is sent to the sub-actor *Executor* (A-09).

In our work, the evolution (or adaptation) is mainly based on direct inputs of the customer.The proposed service evolution strategy in ECE is based on composition (or decomposition in case of service removal) of the current solution or the parameter change of delivery conditions. For each primary input, the detailed strategy is presented below.

Situation (a): adding a care need *x*.

The newly added care need is not covered by current solution of the customer; therefore, adding a new care need implies the adaptation of the integrated {service, provider} pairs. It is possible to classify this adaptation into two categories:

- (a1) Identifying (in the current solution) a {service, provider} pair that covers the new care need (the solution is not changed).
- (a2) Adding a new {service, provider} pair that covers the new care need.

So the process should identify if the current solution satisfies the new care need. If so, the process ends. Otherwise, the {service, provider} fragments which cover the new care need ***x*** are identified in order to extend the current solution (based on adherence value resulting from the SCoPE method).

Figure 5.3 shows (at a high level) this sequence of adaptation to the new customer's request.

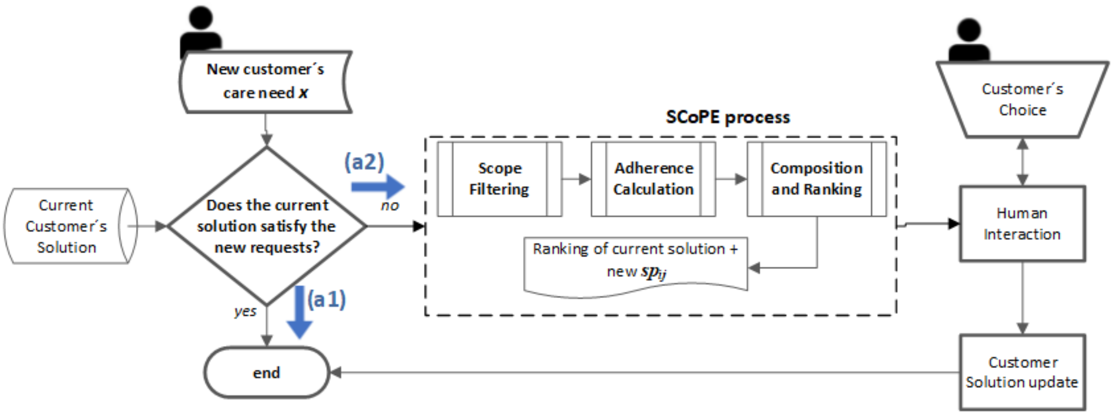


Figure 5.3: Situation (a) – Evolution plan for customer´s care need addition

Situation (b): removal of a care need *x*.

This removal should not affect the current solution for the other care needs. So, two cases are considered:

- (b1) Removal of {service, provider} pair that covers the *x* care need (if this pair does not cover any other need).

- (b2) Change of {service, provider} pair that jointly covers *x* and other care needs (for instance a care need *y*).

The immediate removal of a {service, provider} pair fragment (without prejudice to the current solution) can only be done if it is exclusively attending the *x* care need. In this situation (b1) , the {service, provider} pair fragment is eliminated along with the obsolete care need, and the calculation of the solution adherence is updated.

Otherwise (b2) , the {service, provider} pair fragment that is attending care needs *x* and *y* goes through a new process of calculating the adherence (SCoPE method) considering now only the care need that remains (*y*). The fragment can be updated if there is a better service adherence to *y*. The adherence is calculed by the SCoPE process previous described in Chapter 4. This process can be repeated when other care needs are also covered by the same fragment. A workflow of the evolution plan to customer's care needs removal is illustrated in Figure 5.4.

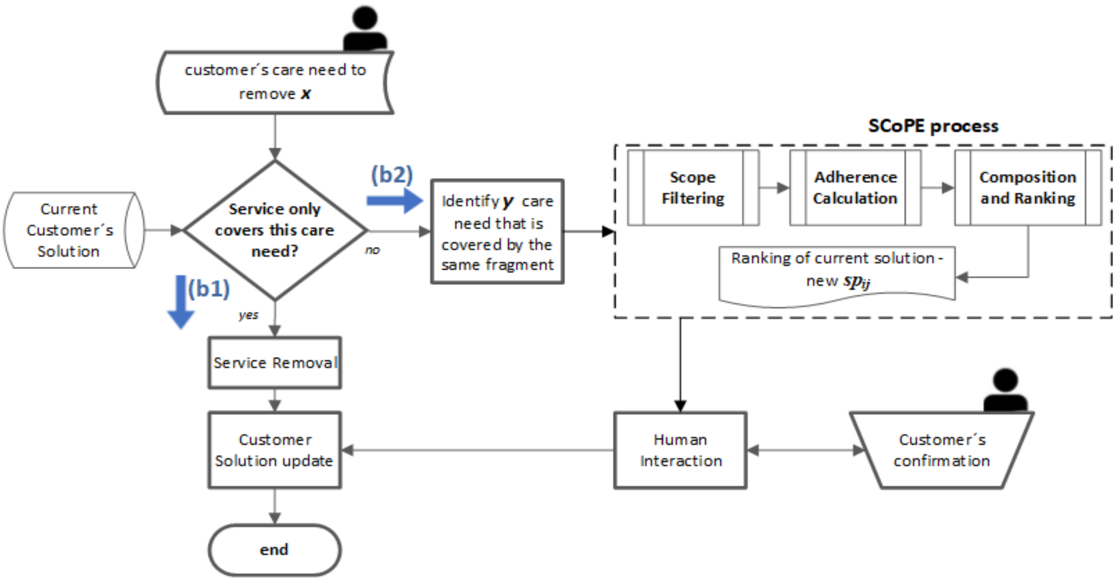


Figure 5.4: Situation (b) – Evolution plan to customer´s care needs removal

Situation (c): modifying parameters of a care need.

In this situation, the customer's care needs remain the same. However, specific requests are modified in ECE, for example, the customer usually requires a transportation service once a week, but for the next month, it will be twice a week (frequency parameter); the customer had a collective transportation service, but now she/he wants private transportation (service features parameter), etc.

The evolution plan to change a care need parameter (see Figure 5.5) involves two stages:

- (c1) Identify the parameter which should be changed checking if the new value is available for the current solution.; or
- (c2) Find a {service, provider} pair available that attends the new parameter.

For illustration purposes, each situation of the evolution plan is exemplified taking into account the solutions shown in Table 4.10 at the end of Chapter 4). Let us imagine that Mr. Silva has chosen the solution 3 (sp_{11}, sp_{21}) two / three years ago, and now he also needs the transportation service (newly identified care need *n*), and the solution will evolve. In the first analysis, sp_{21} service covers the *homeSafety* care need, but the ECE verifies that it is also available for *transportation* services covering the new request and representing a (a1) evolution plan. The solution is the same with new aggregated values (*GA, Cost, and Ranking: GA/Cost (%)*). On the other hand, if the current solution is solution 2 (sp_{64}), a new {service-provider} pair would have to be found to compose the solution representing a (a2) evolution plan.

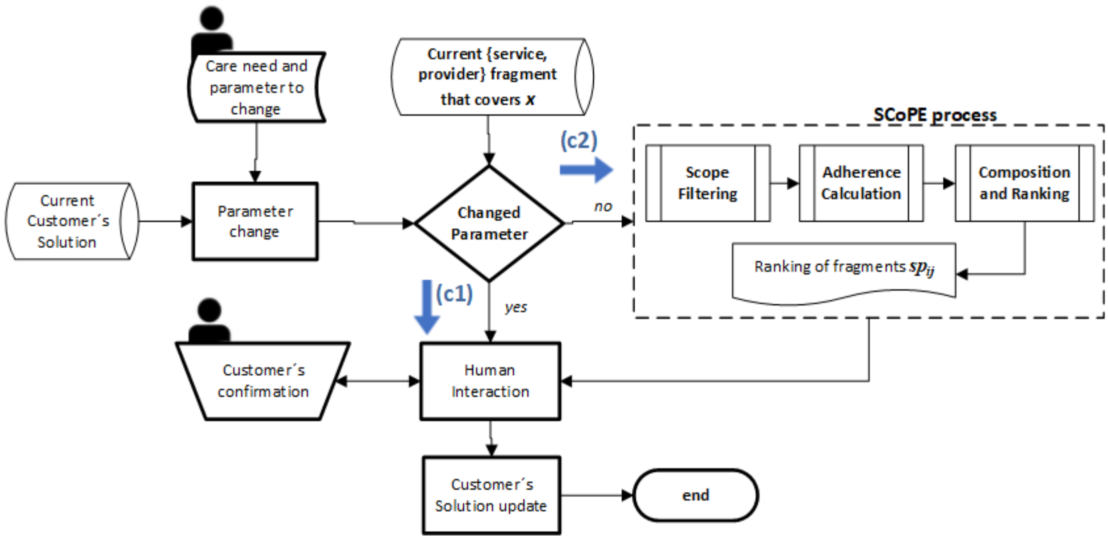


Figure 5.5: Evolution plan for customer´s care need parameters change

The same solution 3, in the (b) situation that removes the care need *m* (for instance, Mr. Silva no longer needs *bloodPressure* care need) the sp_{11} pair is removed from the current solution representing a (b1) evolution plan. However, considering solution 2, sp_{64} pair covers both care needs (*bloodPressure* and *homeSafety*) and cannot be immediately removed (b2 situation).

In the evaluation plan - (c) situation: modifying parameters of a care need - a parameter of service needs to be changed, for instance, Mr. Silva measures the tension once a day, but now he needs to do it three times a day, thus *frequency* parameter is modified (c1 situation), or if it is not possible, a new service is found to replace the existing one (c2 situation).

5.2.4 Sub-actor *Executor*

The sub-actor *Executor* (A-09) executes the action and the solution is adapted according to new requirements. The task *Reaction strategy planner* (T-12) calculates the rating of the evolutionary solution (task *Solution rating* (T-13)) and identifies the disturbance in relation to the old solution (task *Disturbance identification*(T-14)). In the next step the human-in-the-loop is started and the ECE broker together with the customer confirms (or declines) the new proposed solution (task *Human interaction* (T-15)), and the solution is updated (task *Solution update* (T-16)).

5.3 ECE Processes

As previously mentioned in Section 3.1, the ECE environment supports three main process related to care services: Preparation, Execution and Monitoring, and four environments: ECE Information System and ECE Manager System (presented in Chapter 3), ECE Personalization System (presented in Chapter 4) and ECE Evolution System (presented in the current Chapter 5).

To demonstrate the integration of environments and their roles step by step i.e. how the work is completed from start to finish, a workflow diagram is presented in Figure 5.6. This diagram illustrates the main process flow segregated into five lanes (ECE Manager System, Customer, Service Provider, ECE Personalization System and ECE Evolution System). The described processes are implemented in a software prototype. A brief description of each process of Figure 5.6 is presented in the Table 5.1.

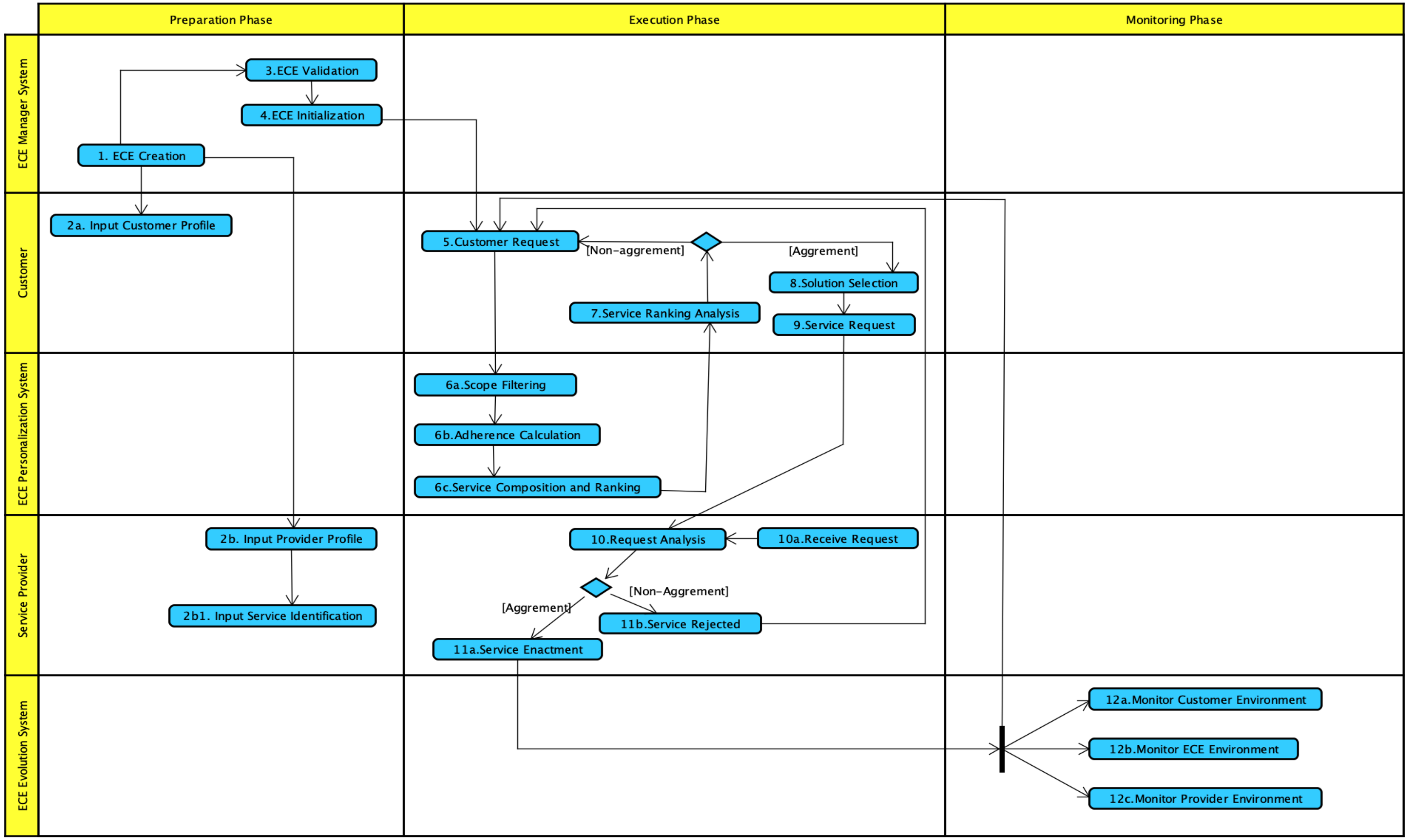


Figure 5.6: ECE workflow diagram segregated by five lanes

Table 5.1: Brief description of each sub-process of Figure 5.6

Phase	ID	Activity	Lane	Description
Preparation	1.	ECE Creation	ECE Manager System	ECE definition of its rules and functionalities. Characterization of ECE profile templates identifying the proposed care need taxonomy.
Preparation	2a.	Input Customer Profile	Customer	Customer profile implementation. Registering a customer.
Preparation	2b.	Input Provider Profile	Provider	Service provider profile implementation. Registering a service provider.
Preparation	2b1.	Input Service Identificatio n	Provider	Service profile implementation. Registering a service linking with the provider.
Preparation	3.	ECE Validation	ECE Manager System	Validation of all elements to start the execution process. There is at least one item in each profile (or a minimum established in the ECE Creation).
Preparation	4.	ECE Initializatio n	ECE Manager System	Release to wait for customer´s input.
Execution	5	Customer Request	Customer	Filling out customer choices and preferences. Collecting data for the service request.
Execution	6a.	Scope Filtering	ECE Personalization System	Filtering potential services to attend customer request based on care needs taxonomy.
Execution	6b.	Adherence Calculation	ECE Personalization System	Calculating the adherence between customer request and potential services found in the scope filtering activity.
Execution	6c.	Service Compositio n and Ranking	ECE Personalization System	Building the matrix of proposed solutions to customer, ranked by service adherence.

Execution	7.	Service Ranking Analysis	Customer	Analyzing the proposals presented if they are in accordance with what the customer intends (in the-human-in-the-loop action). If not, return to the initial form of execution (activity 5. Customer Request). If so, proceed to Service Selection.
Execution	8.	Solution Selection	Customer	Human-in-the-loop for confirmation of selected solution.
Execution	9.	Service Request	Customer	After favourable evaluation by the customer, approval is given to submit the solution to the involved service providers.
Execution	10.	Request Analysis	Provider	The business partners (which are member of the ECE) respond to the customer request.
Execution	10a.	Receive Request	Provider	Provide analysis data and adjust business strategy if necessary.
Execution	11a.	Service Enactment	Provider	Deliver Service Solution.
Execution	11b.	Service Rejected	Provider	There was no agreement between the partners in the provision of the service. Return to form 7. Service Ranking Analysis.
Monitoring	12a.	Monitor Customer Environment	ECE Evolution System	Identify new care needs or obsolete care needs of the customer.
Monitoring	12b.	Monitor ECE Environment	ECE Evolution System	Promote input or remove services, input or remove service providers, and ECE Manager is changing rules or strategies.
Monitoring	12c.	Monitor Provider Environment	ECE Evolution System	Service providers are doing update on their services.

The previous main processes are needed to provide an adaptive system that can work well with an ECE framework to service personalization and evolution.

5.4 Summary

In this chapter, we present a view of the influence of evolutionary and adaptive systems through the MAPE-k control loop structure. We propose a service evolution method (SEvol) to support the adaptation process (evolution) of current customer’s solution to new requests.

Following MAPE-K, the SEvol method is based on a control loop composed of four main stages: (Monitor) monitoring events that occur in the surrounding physical and social context; (Analyzer) analyzing monitored data against solution requirements to identify need of adaptation; (Planner) devising an evolution strategy that reconciles current solution with a new customer´s context; and (Executor) enacting such strategy while minimizing disturbances caused by suggested solutions. The K corresponds the current customer´s solution. Providing an intentional description of processes in terms of process elements and the rationales behind them, the Evolution System was explained through an i* rationale strategic model.

In the developed system, the evolution is based on direct inputs from the customer. We consider as primary inputs to the evolution process: (situation a) the identified new care need, (situation b) indication that a care need is no longer present, and (situation c) indication that a service changed the delivery conditions. These situations were detailed and examplified (consering the illustrative example showed in Chapter 4) in the sub-actor Planner. A human-in-the-loop action is realized in the element *Executor*, characterizing the evolution system has a semi-dynamic adaptation case.

In the end, a workflow diagram is presented considering the main processes of ECE, demonstrating the roles of the ECE environments and the main stakeholders, segregated in the three stages of: preparation, execution and monitoring. This proposal is intended to provide an adaptive system that can work within an ECE framework to service personalization and evolution. Details about each sub-process are summarized in Table 5.1.

6

ECE Evaluation

This chapter presents the evaluation process used for the ECE framework. The validation methodology consists of practical and theoretical perspectives. Practical aspects involved the evaluation of utility and applicability of ECE framework. A prototype including the core concepts of the ECE was developed to show the feasibility of our approach. Moreover, a survey was conducted to assess the acceptance of the proposed technology. Theoretical aspects of the ECE framework were evaluated by the research community through contributions to panels, presentations, and publications.

6.1 Validation Methodology

This section presents the adopted evaluation process for the proposed approach to elderly care. Since our work spans from conceptual models to prototype implementation, the evaluation process needs to assess different dimensions of the generated artefacts, including the applicability of the approach and its utility. Table 6.2 shows the main items and the evaluation areas applied to our approach.

The proposed solution for elderly care comprises three main artefacts: the ECE conceptual framework, the ECE personalization process, and the ECE evolution process. These artefacts are evaluated in terms of their applicability and utility. Applicability is evaluated using case studies where different scenarios are applied. Moreover, a survey was conducted with professional experts to evaluate the perceived utility of the proposal.

Table 6.2: ECE evaluation approach

Artefact (Who)	Parameters (What)	Mean (How)	Based on	Section
✓ **ECE Framework** ✓ **ECE Personalization System (SCoPE method)** ✓ **ECE Evolution System (SEvol method)**	Applicability Utility	Case Studies Prototype Survey Simulations	Saunders (2011) recommendations and Technology Acceptance Model (TAM) methodology, adapted from (Davis et al., 1989)	6.2
✓ **ECE Framework:** ▪ **ECE Conceptual Model; ECE Personalization System (SCoPE method), and ECE Evolution System (SEvol method).**	Evaluation by the research community	Publications Presentations Panels	Evaluation by peers	6.3

6.2 Evaluation of the Framework Applicability and Utility

The applicability and utility of the ECE are evaluated by an empirical study using elements of service composition, personalization and evolution processes. We developed a prototype for proof-of-concept purposes involving the main functionalities of the ECE, including the implementation of algorithms for service composition, personalization and evolution. This prototype was submitted to a business focal group to assess the perceived utility of the system. Personal semi-structured interviews were also used, starting with a narrated tutorial and followed by a survey to collect the necessary data.

The next sections present the elements of the ECE framework used during the experiments, describe the software prototype, present the validation process, and finally, describe the survey elaboration to collect data from the experts in the target application domain.

6.2.1 ECE Feature Selection

A subset of ECE features (core functionalities) were selected to be implemented in a prototype, since only part of them are necessary for the conducted experiment. Figure 6.1 shows the selected subset of ECE elements implemented in the proof-of-concept prototype regarding the SCoPE and SEvol methods.

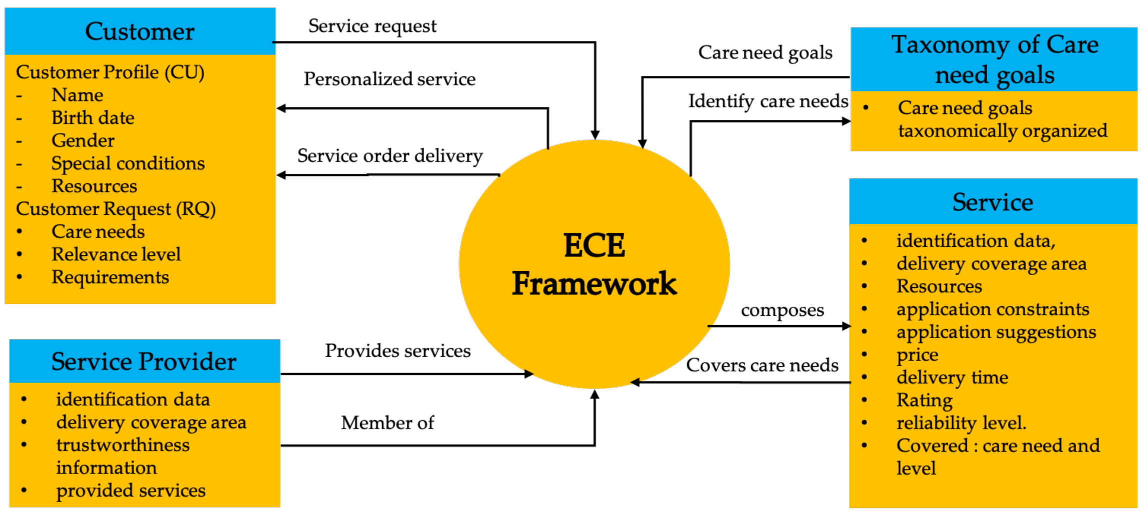


Figure 6.1: Mapping of subset of selected elements and functionalities

The main information elements included in the prototype are briefly presented as follows:

- ✓ Customer (profile and request) (CU, RQ): the customer needs to input personal data, special conditions, and resources. The key elements from the customer´s request include the care needs identification and respective relevance, and requirements description.
- ✓ Service Provider (SP): needs to define the business strategy environment constraints. The main information items here are: identification data, coverage area of service delivery, trustworthiness information, and provided services.
- ✓ Service (SE): the service data part is fundamental to support the customer request. The main information items are: identification data, main area, delivery coverage area, resources, application constraints, application suggestions, price, delivery time, rating, and reliability level. The service

model also identifies the care needs that are covered and their respective coverage levels.

- ✓ Taxonomy of Care Need Goals (TX): the care needs are organized in a taxonomy that plays a key role in linking the service to the care need, and the customer request to the care needs. Each service attends one or more care needs of the taxonomy with an associated coverage level. From the customer's side, each customer requires one or more care needs and identifies their respective relevance.

6.2.2 ECE Software Prototype

✓ **Prototype implementation**

A version of ECE was implemented as a prototype and fed with the necessary information elements to demonstrate its basic operations (inclusion, exclusion, consultation of customer, care needs, services, services providers) and the processes of personalization and evolution of care services.

The programming language environment used to develop the ECE prototype is PHP by Laravel Framework and Laragon web service. Laravel is a free, open-source PHP web framework intended for web app development that follows the model-view-controller (MVC) architectural pattern. Some of the features of Laravel are a modular packaging system with a dedicated dependency manager, different ways for accessing relational databases, and utilities that aid in application deployment and maintenance (He, 2014). Laragon is adequate for building and managing web applications and it is announced to be focused on performance - designed around stability, simplicity, flexibility and freedom (He, 2014).

✓ **Preparation Phase: ECE Setup and Configuration**

Figure 6.2 presents the use case diagram including the main actors and processes of the prototype setup and configuration. In this stage, the validation of the elements to start the execution process is done. There is at least one item in each profile (customer, taxonomy, service provider, and service) that must be registered.

The taxonomy (TX) is registered by the ECE Manager (Register Care Need Taxonomy). Only one instance of the taxonomy exists for each ECE. The taxonomy can evolve over time and new nodes can be added as well updated or deleted. The customer (*Register Customer*), service provider (*Register Service Provider*), and service profile (*Register Service*) are registered through predefined templates.

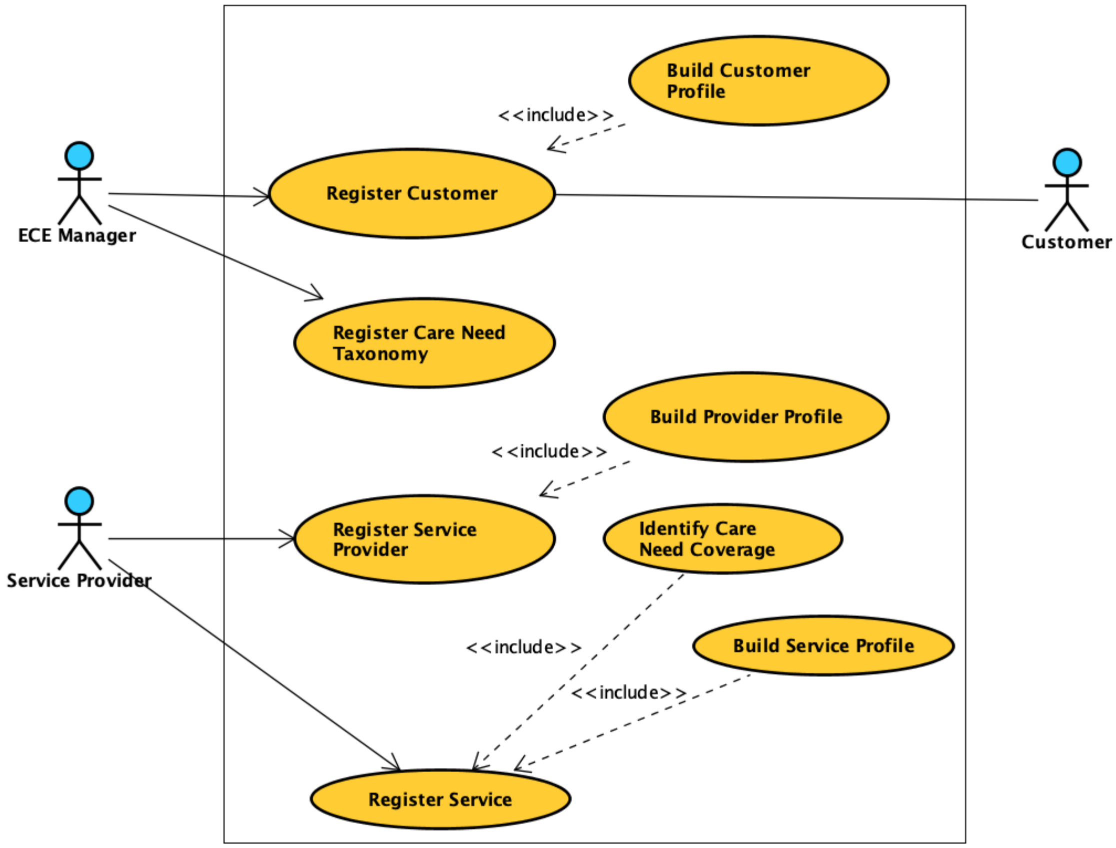


Figure 6.2: ECE Preparation Phase Use Case Diagram

The menus of ECE, linked with profile records, are characterized by TX (care needs taxonomy), Customers, Service Providers, and Services. For each menu, various processes are included: addition, removal, show, and link between elements. Figure 6.3 shows the functionality of Customer menu.

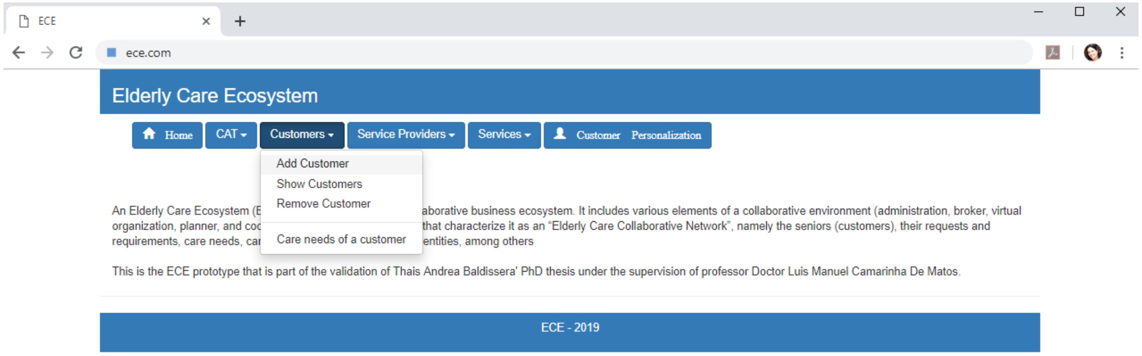


Figure 6.3: Customer Addition Menu

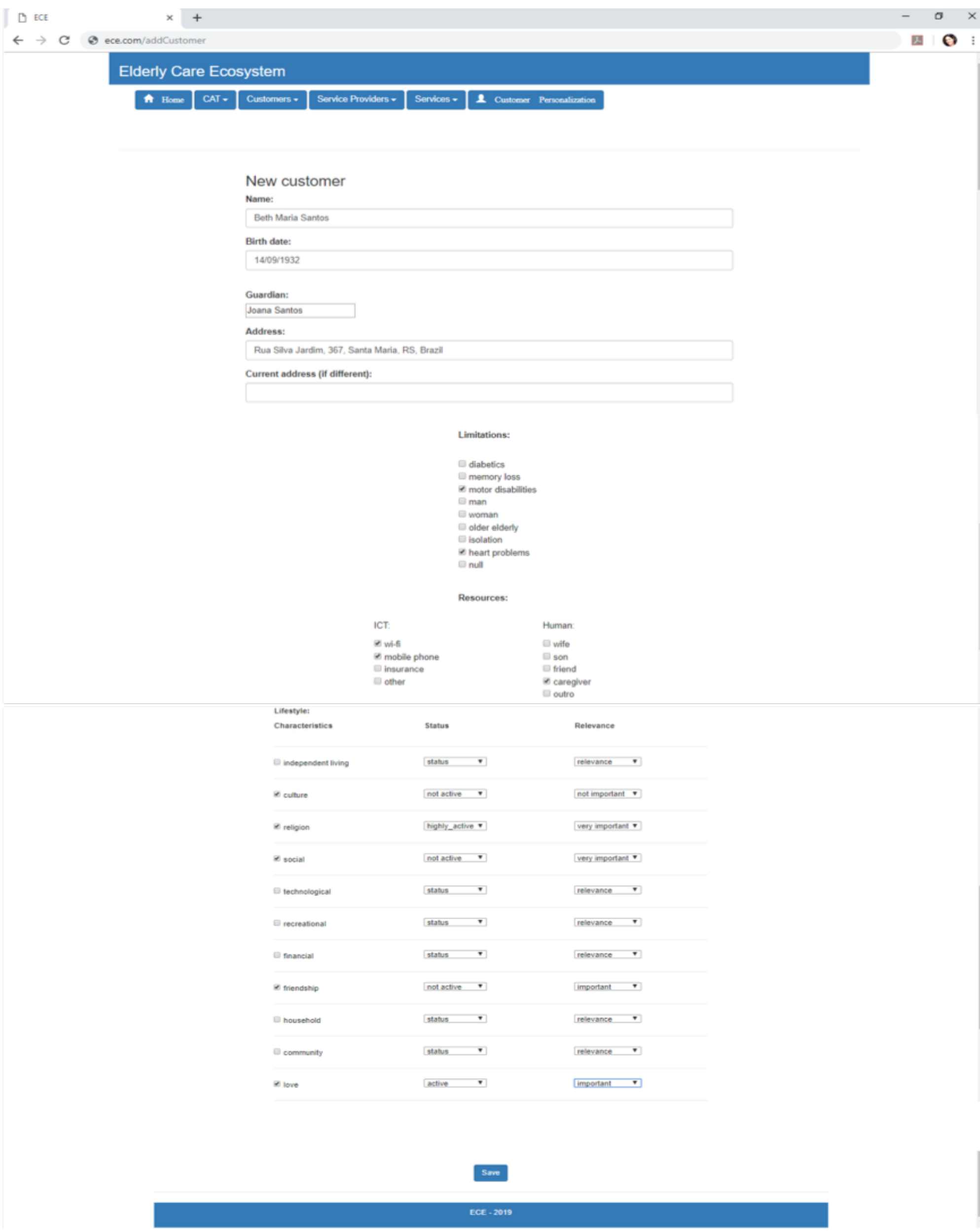


Figure 6.4: Customer Registration

The customer profile is registered through the customer register page, which is presented in Figure 6.4. In this example, the customer *Beth Maria Santos* is inserted in ECE with her personal data, limitations and resources, and lifestyle characteristics.

The Service registration in the ECE is performed through the service registration page shown in Figure 6.5. In this example, the service *Home Care* is inserted in the ECE portfolio and its individual data (name, description), link to care needs taxonomy (covered care needs and corresponding coverage level), needed resources (technological and human), application constraints (corresponding to the link to customer limitations), and application suggestions (corresponding to the link to customer lifestyle characteristics that can be improved) also are entered.

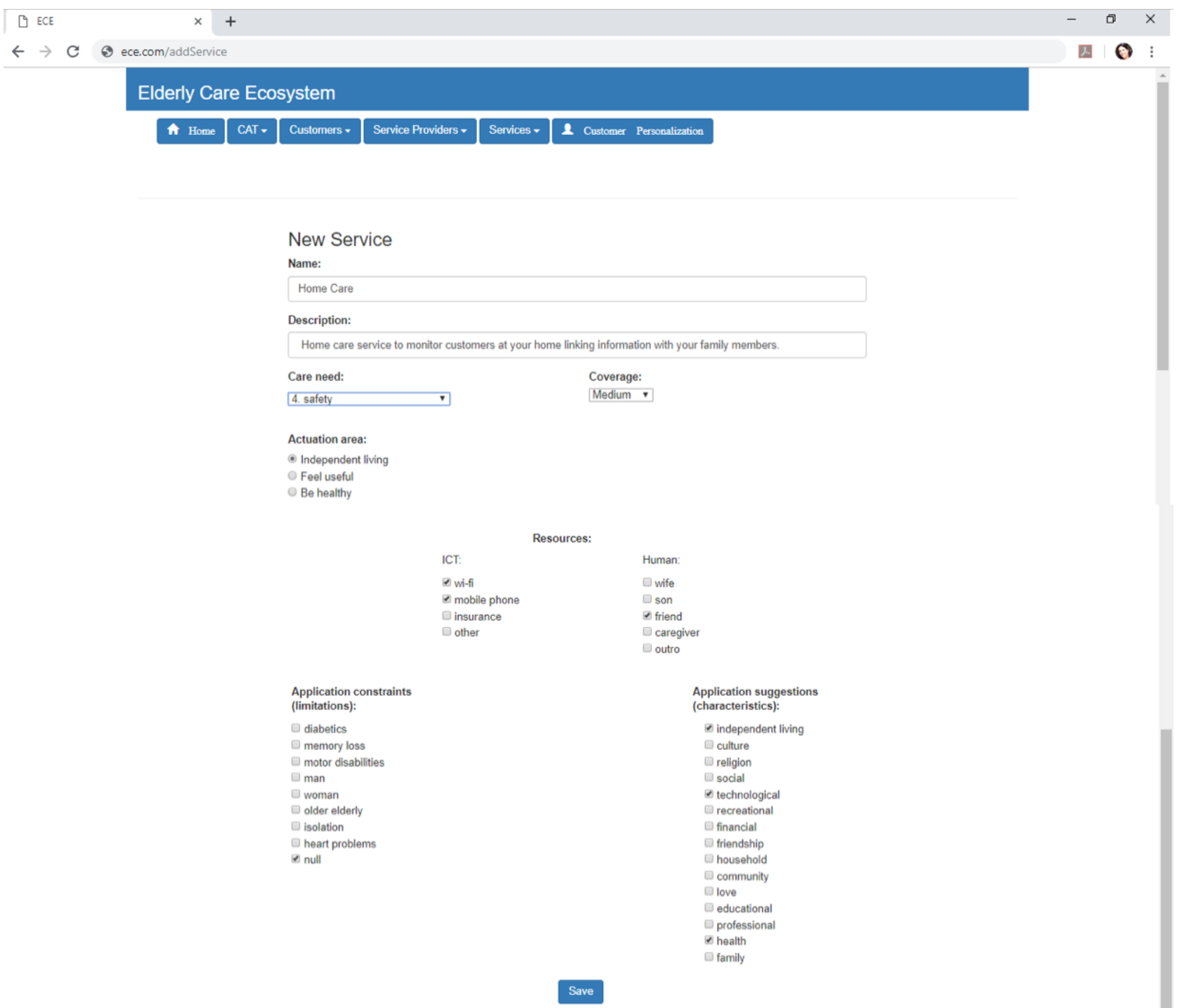


Figure 6.5: Service Registration

After the services registration, the service providers are inserted. Similar to the process of adding a new customer, a new service provider will have to provide various information items, namely the services it provides (considering that the services are already registered), and some of its characteristics. The location where the service can be delivered is indicated by triangular coordinates. The services provided by the service provider are associated to the covered care needs and service requirements.

- ✓ **Execution Phase: Customer request and SCoPE algorithm execution**

The ECE execution phase covers the following main activities: Customer request, and SCoPE algorithm execution. Figure 6.6 presents a partial use case diagram of this phase. The ECE Manager selects the customer (*Select Customer*) and registers her/his request (*Register Customer Request*). The personalization algorithm (SCoPE) is executed (*Execute Personalization Algorithm*) by the *Solution Processor* and a list of solutions is processed and presented to the customer (*List Solution*). The customer chooses the best solution for her/him (*Solution Validation*).

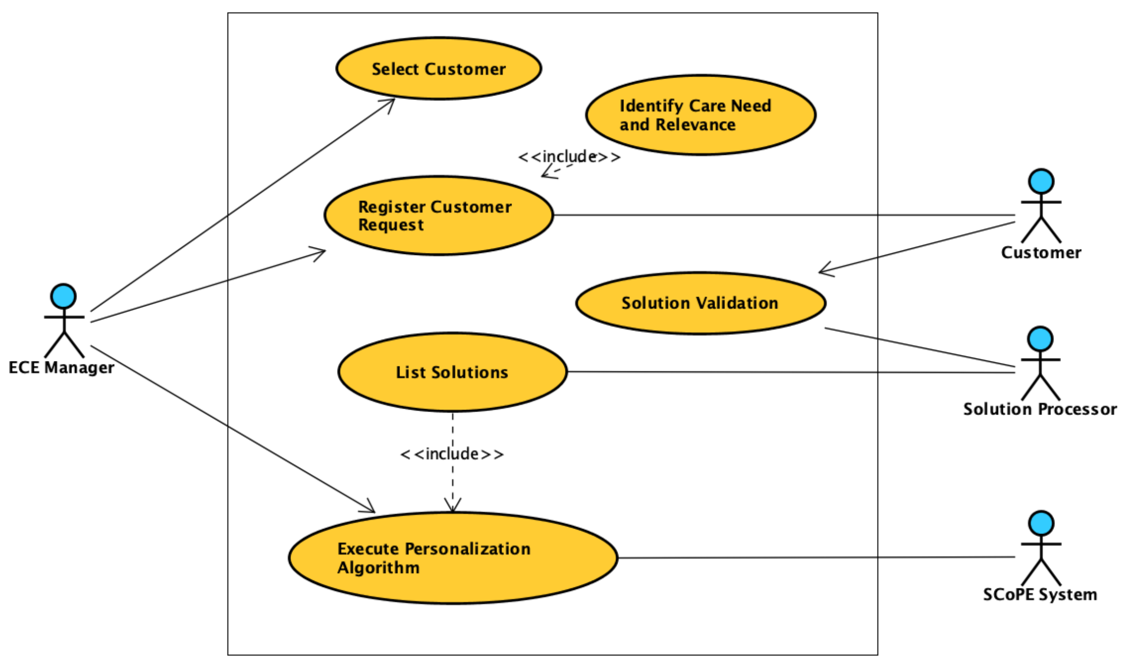


Figure 6.6: Customer Request and Algorithm Execution Use Case Diagram

Once the customer request (new or update) registration is done, the algorithm execution can start. The general solution is presented in Figure 6.7.

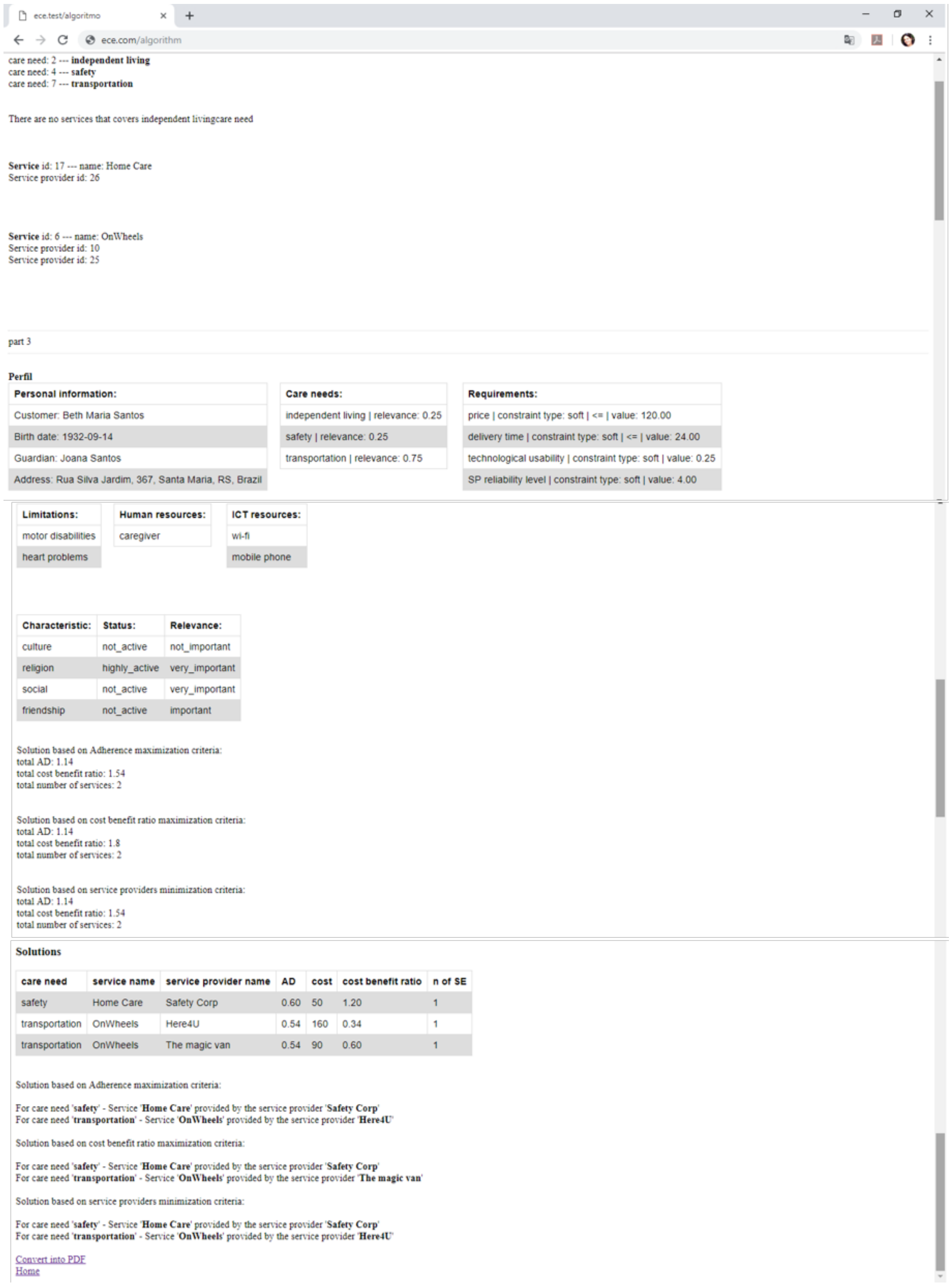


Figure 6.7: General Solution

✓ **Monitor Phase: Evolution**

The ECE monitoring phase covers the following main activities (see Figure 6.8): *Receive Inputs* including update of customer request (*Customer Request Update*), *Evolution Algorithm Execution* (SEvol) resulting in the new solution (*Evolutionary Solution*), and validation of the evolutionary solution by customer (*Solution Validation*).

The partial steps of service evolution performed by the prototype are presented in Figure 6.9. In this example, the care need *independent living* is removed and the new care need *recreational activities* is added with relevance *high*. After the evolution algorithm is executed the solution is presented to the customer for validation.

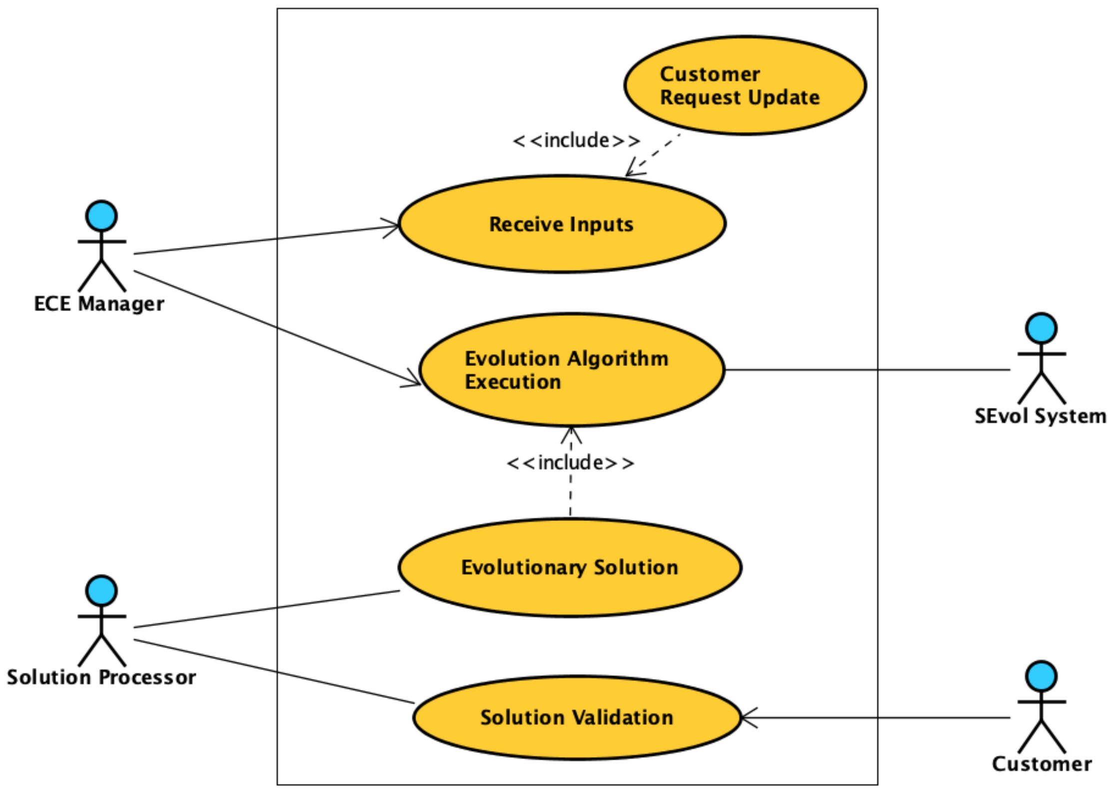
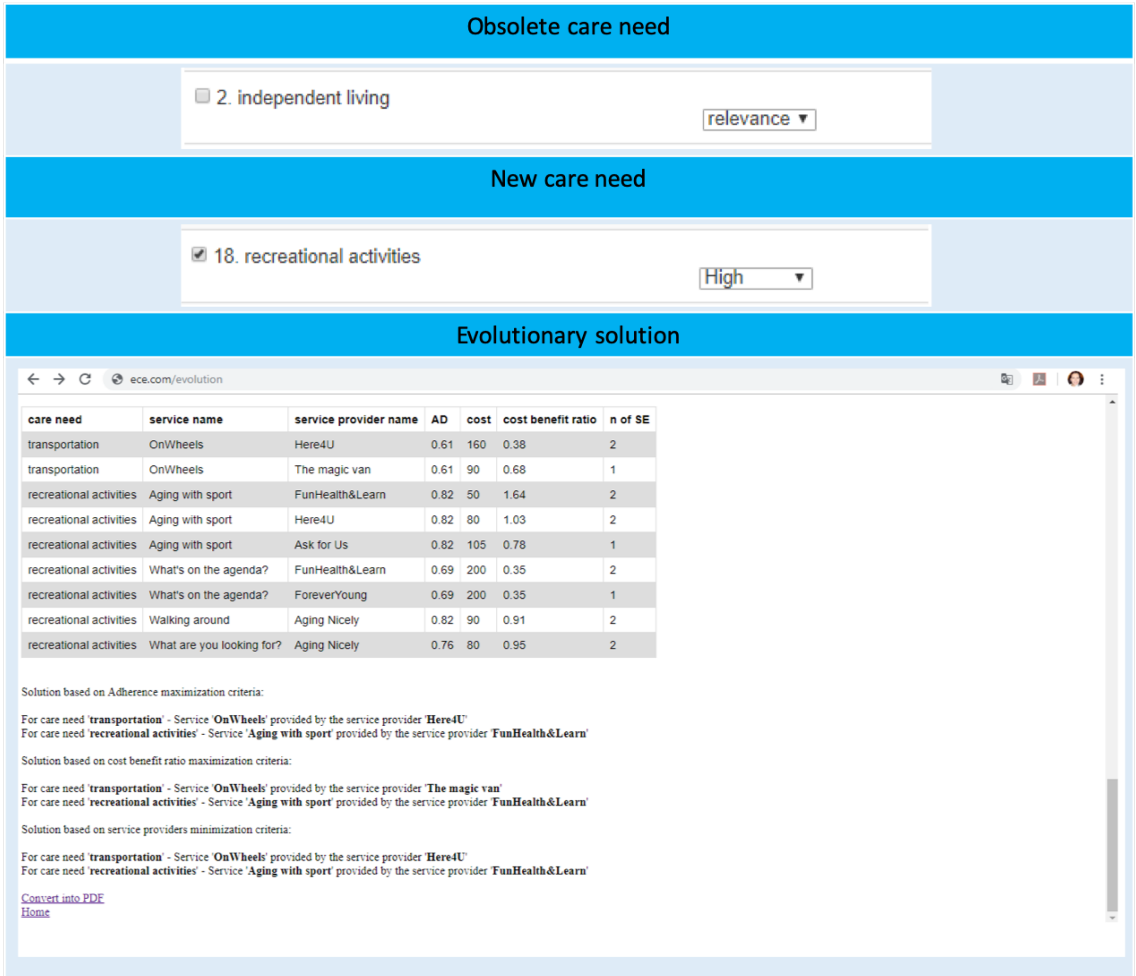


Figure 6.8: Evolution Phase Use Case Diagram



care need	service name	service provider name	AD	cost	cost benefit ratio	n of SE
transportation	OnWheels	Here4U	0.61	160	0.38	2
transportation	OnWheels	The magic van	0.61	90	0.68	1
recreational activities	Aging with sport	FunHealth&Learn	0.82	50	1.64	2
recreational activities	Aging with sport	Here4U	0.82	80	1.03	2
recreational activities	Aging with sport	Ask for Us	0.82	105	0.78	1
recreational activities	What's on the agenda?	FunHealth&Learn	0.69	200	0.35	2
recreational activities	What's on the agenda?	ForeverYoung	0.69	200	0.35	1
recreational activities	Walking around	Aging Nicely	0.82	90	0.91	2
recreational activities	What are you looking for?	Aging Nicely	0.76	80	0.95	2

Figure 6.9: Evolutionary Solution - Partial Steps

6.2.3 Validation Process

Frequently, a mix of methods is used to validate the results of a research work (Pedersen et al., 2000). In particular, the Constructive Research method (Kasanen et al., 1993) can help validating applied research in the area of design science. Validation in design science is performed by building one or more artefacts that solve a domain problem, in order to create knowledge on how the problem can be solved and show how the solution is new or better than the previous ones.

The ECE framework and methods are evaluated in terms of their applicability and utility considering an adaptation of the Technology Acceptance Model (TAM) methodology (Davis et al., 1989). TAM is focused on the intention to use a new technology or innovation. TAM was specifically developed to explain and predict the acceptance of information and communication technologies by potential users.

The main goal of this validation is to verify if the functionalities presented by the implemented subset of elements and the proposed methods fit the objectives of the research work, and if their usability is easily assimilated.

- ✓ **Case study**

We illustrate the use of the ECE by considering a scenario containing a hypothetical individual profile and her care needs, a set of providers available in the ECE as well as a set of services provided by these providers. During the application of the survey, we could have access to some questionnaires that companies apply to assess and build customers' profile. However, for a matter of confidentiality, we could not have access to real data. Thus, we built profiles based on public data available on companies' websites to reflect as close as possible real situations.

- ✓ **Customer Profile**

Mrs. Santos is an 82 years old woman who lives in Porto Alegre, a city with 1.409 million people located in Brazil. It is the capital of Rio Grande do Sul state, the southernmost state in Brazil. Since her husband died 10 years ago, Mrs. Santos lives alone. She has health limitations, mobility impairments, and vision impairments as well. She is hypertense and takes daily medication to maintain blood pressure at normal values. She lives in a two-story house and uses a stair lift to move between floors. Her house is a little isolated from others in the neighborhood and Mr. Beth feels constantly unsafe, especially at night. Also, Mrs. Santos has four-degree myopia, which makes her unconfident to walk outside home. Mrs. Santos does not go out frequently for social activities. However, she would like to have more opportunities to visit some places in the city. Religion is a very important matter for Mrs. Santos and she goes to Sunday Morning Mass, whenever Susan, her old friend, is available to accompany her. Mrs. Santos watches TV almost all day and prefers popular TV shows and sports rather than documentaries and films. She has a housekeeper who helps her once or twice a week to tidy up the house. She schedules the housekeeper using a smartphone app, which is made available by a cleaning company. Mrs. Santos has a close relationship with her family. She has a son and a daughter, who frequently visit or contact her by phone. Although Mrs. Santos is living alone for a decade, she does not rule out the possibility of having another romance. Currently, there are two main areas that Mrs. Santos would like to improve very soon: assistance for transport and safety. We summarize Mrs. Santos profile in Table 6.3.

Table 6.3: Mrs. Santos Profile

Customer profile			
Property	**Description**		
Name	Beth_Maria_Santos		
Personal Attributes	Birth date: Sep, 14 - 1932		
Health Limitations	L1:hypertense (two gauges daily) L2:mobility_less (constantly pain in the legs) L3:vision_problem, glasses utilization (four-degree myopia both eyes)		
Financial Limitations	L4: total investment: $120/month		
LifeStyle	**Characteristic**	**Status**	**Relevance**
	Cultural	no_active	no_important
	Religion	very_active	very_important
	Social	no_active	very_important
	Family	active	important
	Love	no_active	important
Resources	R1: mobile_phone (Android, ability to basic functionality and specific apps) R2: Internet R3: Housekeeper (once or twice a week)		
Localization	Santa_Maria_RS_Brazil		
Care needs	**Care need**	**Relevance**	
	ca1:safety	very_high	
	ca2:transportation	high	
Guardian	G1:Joana_Santos_joana.santos@gmail.com		

✓ **Providers Profile**

For this experiment we consider a set of six providers available in the ECE. We describe each provider's profile as follows.

Safety Corp: is a multinational company specialized in home security technologies. This company is fully dedicated to the elderly community and provides surveillance services, such as IP monitoring cameras, alarms, and sensors. The Safety Corp's actuation is limited to the south of Brazil, where it has a good reputation (4.0/5.0).

Love Corp: is an online dating platform specialized in elderly community that allows users to pay for a service called "safe dating". Safe dating includes professional profile analysis and support for first physical meetings. It is a world-wide company operating in more than 100 countries. Currently, Love Corp has a satisfaction rating of 4.3.

Bella Tour: is a company specialized in group transportation and short trips. It offers different sizes vans for transportation of individuals or group to social events. It works 24/7 and attends customers in any area of Porto Alegre, Brazil. Its reputation is 4.0.

Go Senior: is a company that offers services that help seniors and families to request Uber-type transportation services. Go Senior offers the possibility of requesting Uber services using automated services by phone (without the need of smartphones) or asking for an operator. The company aggregates value to the Uber service by allowing families to receive minute-by-minute updates and interact via text with Go Senior to transmit some message to the senior during the itinerary. Additionally, Go Senior allows seniors to request a pre-configured grocery list using the automated or personal phone service. It is a 24/7 service attending all Brazilian territory, where its reputation reaches 4.8.

Seniors are Us: is a local company that offers remote monitoring and reporting solutions. Seniors are Us is a high-tech company specialized in data processing and reporting. It provides a range of home sensors and wearables for seniors that collect several data from the environment and from individuals. For example, it can monitor whether the elderly took breakfast or not, if she/he took the pills on the right time, if she/he is stuck for a long time or doing exercises, or even collect gauge blood pressure, temperature, and behavior during sleeping. Seniors are Us services are available only in certain areas of Porto Alegre and its reputation is 4.2.

AllSafe Corp: is a national enterprise that provides personal security. The company has a long tradition in providing security resources to individuals and organizations in the whole Brazilian territory. Safe Corp has a reputation of 4.8 in the ECE.

We summarize these service providers profile and respective services in Table 6.4 and Table 6.5.

Table 6.4: Service providers profiles

Service_Provider_01	Safety Corp
Organizational Attributes	Security services for home care
Reputation	4.0/5.0
Competences	c1: senior specialized
Geographic area	South of Brazil
Provide services	SE_01: Home_Care_Service SE_08: PSecurity
Service_Provider_02	Love Corp
Organizational Attributes	Dating digital platform for elderly
Reputation	4.3/5.0
Competences	c1: personalized services c2: senior specialized
Geographic area	World-wide

Provide services	SE_02:Safe_Dating
Service_Provider_03	Bellatour_Corp
Organizational Attributes	Transportation
Reputation	4.0/5.0
Competences	c1: experienced professional drivers c2: specialized in groups for social events (theatre, cinema, shows, etc.) c3: female driver available
Geographic area	Porto Alegre, RS, Brazil
Provide services	SE03:Easy_Trans
Service_Provider_04	Go Senior
Organizational Attributes	Senior Transportation
Reputation	4.8/5.0
Competences	c1: Itinerary tracking c2: senior specialized
Geographic area	All Brazilian territory
Provide services	SE_04: MegaUbber SE_05: Easy Market
Service_Provider_05	Seniors are Us
Organizational Attributes	Remote Monitoring and Reporting
Reputation	4.2/5.0
Competences	c1: personalized services c2: senior specialized
Geographic area	Brazilian territory
Provide services	SE_03: Alarm SE_04: Monitor
Service_Provider_05	AllSafe Corp
Organizational Attributes	Personal Security services for home care
Reputation	4.8
Competences	c1: female security available c2: personalized services
Geographic area	Brazilian territory
Provide services	SE_06: Alarm SE_07: PSecurity

Table 6.5: Services Profiles

Service_01	Home_Care_Service
Individual attributes	Monitoring cameras and alarms
Reputation	4.3 / 5
Resources	R1: mobile_phone; R2: Internet
Geographic area	South of Brazil
Price	$50 month (cameras), $30 month (alarms)
Attended care need	Ca1:security; Ca2: accompanists diary tasks
Service_02	Safe_Dating
Individual attributes	Safe dating

Reputation	4.5 / 5
Resources	R1: Internet; R2: Desktop /smartphone
Geographic area	World wide
Price	$ 30 month (online), $100 profile analysis, $150 personal meeting
Attended care need	Ca1:security; Ca2: dating;
Service_03	Easy_Trans
Individual attributes	Van service
Reputation	4.3 / 5
Resources	R1: Phone line
Geographic area	Porto Alegre, RS, Brazil
Price	Single journey - $100
Attended care need	Ca1:transportation
Service_04	MegaUbber
Individual attributes	Ubber request using regular phone
Reputation	4.7 / 5
Resources	R1: Phone line, R2: Smartphone
Geographic area	World wide
Price	Open
Attended care need	Ca1:security; Ca2: transportation
Service_05	Easy Market
Individual attributes	Personalized grocery list delivery
Reputation	3.5 / 5
Resources	R1: Phone line
Geographic area	Porto Alegre, Brazil
Price	$10 per delivery
Attended care need	Ca1:transportation
Service_06	Alarm
Individual attributes	Alarms triggered by events
Reputation	4.8 / 5
Resources	R1: Internet
Geographic area	Brazilian territory
Price	$40 month
Attended care need	Ca1:security
Service_07	Monitor
Individual attributes	Event monitoring
Reputation	4.3 / 5
Resources	R1: Internet
Geographic area	Brazilian territory
Price	$50 per sensor, 0.15 per KByte transmitted
Attended care need	Ca1:security; Ca2:health
Service_08	PSecurity
Individual attributes	Personal security
Reputation	3.8 / 5
Resources	None
Geographic area	Brazilian territory
Price	$300 day
Attended care need	Ca1:security

✓ **Preparation and execution of the interviews to lead users**

The perceived utility and applicabilty of the proposed approach was evaluated by conducting a survey with professional experts in the health and elderly care areas (lead users). The interviews were structured in face-to-face meetings following four steps:

1. Introduction: a brief presentation was given to the participants to explain the goals of the research and its details, including the PhD research project and the protocol involved in the survey.

2. ECE tutorial: participants watched a short video tutorial describing the main features of the ECE (personalization and evolution processes) and applications of the ECE using different illustrative examples.

3. Live demonstration of the ECE prototype: an overview of the prototype was shown to the participants, presenting its main functionalities.

4. Survey: the participants were invited to respond to the survey. The elaboration of the survey is based on TAM (Davis et al., 1989).

6.2.4 Survey Elaboration

The survey is based on and extends the Technology Acceptance Model (TAM) developed by (Davis et al., 1989). This model is a validated instrument that has been extensively studied (Abu-Dalbouh, 2013; Alsamydai, 2014; Gagnon et al., 2012; Lai, 2017; Wu, 2011).

The statements presented in the survey belong to nine dimensions (four originating from TAM and five additional ones created for this specific work) organized in three contexts (built for this evaluation case) that we want to assess: technological context, organization context, and collaborative environment context. Figure 6.10 shows the proposed model, including the traditional and the additional dimensions and contexts.

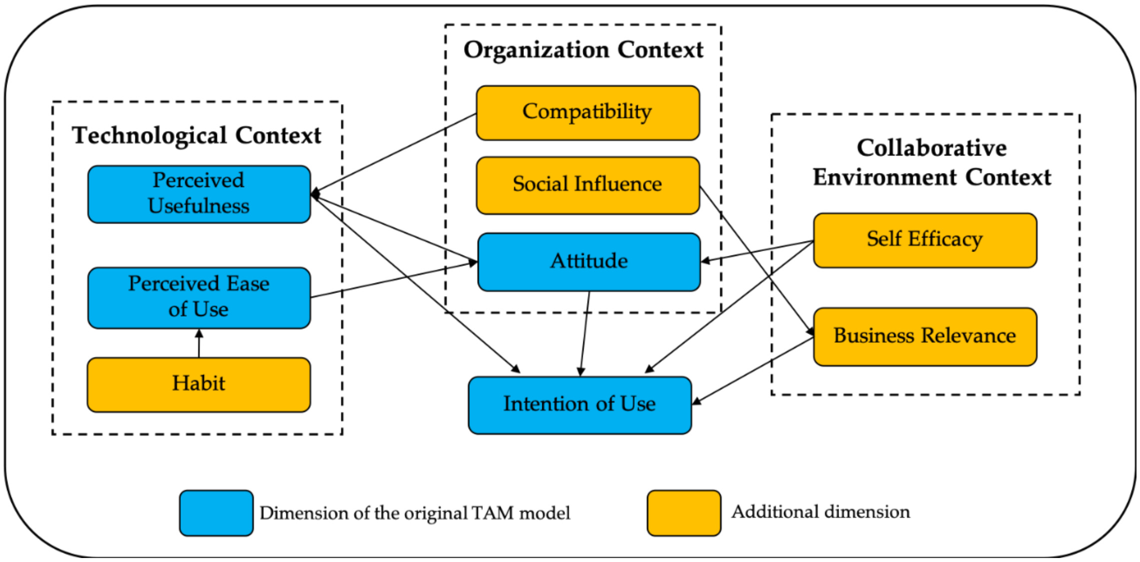


Figure 6.10: Survey Dimensions

The *Technological Context* includes the dimensions *Perceived Usefulness* and *Perceived Ease of Use* from the TAM methodology, as well as the additional dimension *Habit*. *Habit* refers to behavior that has become automatized.

The *Organizational Context*, encompasses the dimensions *Attitude*, *Compatibility*, and *Social Influence*. *Attitude* can be defined as the perception by an individual of the positive or negative consequences of adopting the technology. *Compatibility* refers to the degree of correspondence between an innovation and existing values, past experiences, and needs of potential adopters. *Social Influence* assesses the extent to which an individual believes that stakeholders who are important to him/her will approve his/her adoption of a specific behavior.

Finally, the *Collaborative Environment Context has two* dimensions to be assessed: *Self Efficacy* and *Business Relevance. Self Efficacy* refers to the degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the system. *Business Relevance* represents the influence that innovation can bring to the business. *Self Efficacy* and *Business Relevance* express the needed features/characteristics for participation in a collaborative environment.

In the beginning of the survey, elements about demographic data are also collected. Table 6.6 presents these elements describing the influence and range values for each demographic item.

Table 6.6: Demographic data

Demographic Sphere	Influence	Range values
Gender	The gender is important for segmentation and quantification of the respondents and responses.	[female] [male]
Nationality	Relating to social and cultural aspects that can contribute to different opinions on the same subject.	[Brazilian] [Portuguese] [other]
Age	The age group will often determine the experience.	[18…29] [30…39] [40…59] [60…]
Job	Corresponding the role that the interviewee occupies in the enterprise. The job is relevant to segment responses by roles.	[management] [administrative staff] [service deliver] [caregiver] [other]
Level of Education	A graduated person may answer question differently than those whose education ended before high school.	[less than a high school diploma] [bachelor´s degree] [master´s degree] [doctorate degree] [other]
Background	The basic formation (engineer, manager, technical, etc.) allows to correlate the responses of different backgrounds.	[health] [management] [education] [engineering] [other]
Enterprise type	three types of enterprise are targeted by the survey: private, public, and philanthropic. The type is very relevant.	[private] [public] [philanthropic] [mixed]
Enterprise size	The size of the enterprise can influence the responses (e. g. considering enterprises of the same type).	[large enterprise] [small and medium enterprise] [micro enterprise] [other]
Years in the company	The years that the person works in the company can give an Idea of the commitment in the answers.	[1…3] [4…6] [7…10] [11…20] [21… -]
Experience in the elderly care domain	The experience view is important to produce correlations with the other responses.	[- …1] [1…3] [4…6] [7…10] [11…20] [21… -]
Experience in the collaborative	The experience view is important to produce correlations with the	[no experience] [1…3]

networks domain	other responses.	[4…6] [7…10] [11…20] [21… -]

A set of questions about each variable dimension is the next step of the survey. Table 6.7 shows these questions divided into context environment and dimensions. The questions are not sequentially presented by dimension. Instead, they are mixed along the questionnaire to avoid bias in the responses. Some questions are intentionally similar to others to reinforce responses in a determined dimension and increase the reliability on answers.

Table 6.7: Survey questions classified by contexts and dimensions

Technological Context Questions
Dimension 1: Perceived Usefulness
1. The use of ECE could help me to attend my customers more rapidly
2. The use of ECE may improve the service delivery to my customers
3. In general, ECE may be useful to improve the care service provision to my customers
4. ECE can facilitate the service personalization and evolution to my customers
Dimension 2: Perceived Ease of use
1. I think that I could easily learn how to use ECE
2. I think it would be easy to perform the tasks necessary for the monitoring of my customers using ECE
3. I believe that the monitoring carried out by ECE would be clear and easy to understand
4. I think that the ECE will be easy to use
Dimension 3: Habit
1. I feel comfortable with information and communication technologies
2. I have already used an ecosystem to attend my customers
3. I have already used technologies to build the profile of my customers
4. I think my customer' privacy may be affected by the use of ECE
Organization Context Questions
Dimension 4: Compatibility
1. The use of ECE may imply major changes in my business strategy
2. The customer data profile used by ECE is appropriated to my business strategy.
3. The service data profile used by ECE is appropriated to my business strategy.
4. The provider profile of ECE attend my need to service provision
Dimension 5: Social Influence
1. Most of my customers will welcome the fact that I use ECE
2. Most of my colleagues will welcome the fact that I use ECE

3.	Professionals managers would welcome the fact that I use ECE
4.	Other professionals (service providers, caregivers, delivers etc…) would welcome the fact that I use ECE
Dimension 6: Attitude	
1.	I think it is a good idea to use ECE to recommendation of personalized services to my customers
2.	The use of ECE is beneficial for the monitor my customers and evolution service
3.	The use of taxonomy will improve the service personalization and evolution
4.	In my opinion, the use of ECE´ profiles (service, service provider, customer, and care need) will have a positive impact for service provision
Collaborative Environment Context Questions	
Dimension 7: Self Efficacy	
1.	I think that my organization has the necessary organizational structures and governance models to support my use of ECE
2.	I would use ECE if I receive appropriate training and the necessary technical assistance.
3.	I think that delivered a service to a customer working along with another company is simple with ECE use.
4.	The ECE use can increase competition
Dimension 8: Business Relevance	
1.	Using an ECE can increase my customers
2.	I believe that using the ECE, the risks and resources are shared with my partners
3.	I believe that the ECE represents a vantage competitive in a context of market turbulence
4.	I can lose customers if I do not participate in an ECE.
General Conceptual Model Questions	
Dimension 9: Intention of use	
1.	I have the intention to use ECE when it becomes available in my organization
2.	I have the intention to use ECE to provide personalized services to my customers
3.	I have the intention to use ECE when necessary to provide evolutionary services to my customers
4.	The use of an ECE to monitor my customer is not intrusive and unpleasant

6.2.5 Survey Application and Result Analysis

The questionnaire was tested with 95 elderly care professionals belonging to 17 distinct companies. Respondents answered the questionnaire by rating each item on a 5-point Likert scale (Likert, 1932) ranging from ''totally disagree'' to ''totally agree.'' Scores were developed by computing the mean of all items that constitute each theoretical dimension.

The internal consistency of the instrument was assessed by calculating the Cronbach alpha (Cronbach, 1951) values for each variable. The construct validity of the model was evaluated using interitem correlation analysis. With the exception of

D3: Habit (0.62), Cronbach alpha values were acceptably high (>0.7 by (Nunnally, 1978)) for the remaining theoretical constructs (see Table 6.8).

Table 6.8: Sample item and Cronbach α by dimensions

Dimension	Items used for measure the dimension	Sample item	Cronbach α
D1: Perceived Usefulness	2, 8, 13, and 23,	ECE can facilitate the service personalization and evolution to my customers	0.81
D2: Perceived Ease of Use	3, 9, 14, and 27	I think that I could easily learn how to use the ECE	0.79
D3: Habit	1, 21, 31, and 34	I feel comfortable with information and communication technologies.	0.62
D4: Compatibility	6, 15, 24, and 32	The customer data profile used by ECE is appropriated to my business strategy	0.75
D5: Social Influence	10, 16, 22, and 29	Most of my customer will welcome the fact that I use the ECE	0.82
D6: Attitude	4, 19, 26, and 30	In my opinion, the use of ECE´ profiles (service, service provider, customer, and care need) will have a positive impact for service provision	0.81
D7: Self Efficacy*	12, 28, 35, and 36	I would use ECE if I receive appropriate training and the necessary technical assistance	0.78*
D8: Business Relevance*	7, 11, 17, and 25	I believe that the ECE represents a competitive advantage in a fierce market	0.82*
D9: Intention of Use	5, 18,20 and 33	I intend to use the ECE in my organization when it becomes available	0.90

*considered only for those who work with collaborative networks.

Table 6.9 presents the demographic characteristics of the elderly care professionals who participated of the experiment.

Table 6.9: Demographic Characteristics of the Elderly Care Professionals

Demographic Sphere	Range values and results	Number of respondents	Perceptual %
Gender	[female]	73	76.8%
	[male]	22	23.2%
Age	[18…29]	54	56.8%
	[30…39]	20	21.1%
	[40…49]	17	17.9%
	[50…59]	3	3.2%
	[60…]	1	1.1%
Job	[management]	28	29.5%
	[administrative staff]	31	32.6%
	[medical professional-caregiver]	21	22.1%
	[caregiver]	15	15.8%
Level of Education	[less than a high school diploma]	9	9.5%
	[bachelor´s degree]	33	34.7%
	[master´s degree]	15	15.8%
	[doctorate degree]	5	5.3%
	[other] technical degree	33	34.7%
Background	[health]	49	51.6%
	[management]	39	41.1%
	[education]	2	2.1%
	[engineering]	5	5.3%
Enterprise type	[private]	71	74.7%
	[public]	20	21.1%
	[philanthropic]	2	2.1%
	mixed	2	2.1%
Enterprise size	[large enterprise]	42	44.2%
	[small and medium enterprise]	36	37.9%
	[micro enterprise]	17	17.9%
Years in the company	[1…3]	54	56.8%
	[4…6]	14	14.7%
	[7…10]	15	15.8%
	[11…20]	8	8.4%
	[21… -]	4	21.1%
Experience in the elderly care domain	[…1]	19	20.0%
	[1…3]	57	60.0%
	[4…6]	6	6.3%
	[7…10]	3	3.2%
	[11…20]	6	6.3%
	[21… -]	4	4.2%
Experience in the	[no experience]	70	73.7%

collaborative networks domain	[1…3]	10	10.5%
	[4…6]	8	8.4%
	[7…10]	2	2.1%
	[11…20]	2	2.1%
	[21… -]	3	3.2%

Among the 95 participants in the experiment, 31 individuals work as administrative staff, 36 are caregivers, and 28 are managers. Most of these individuals acts as caregivers as well. More than 76% of respondents were women, and almost 60.4% works in the health care domain. Nearly 56,8% were under 30 years old, 44.3% were between the ages of 30 and 60, and only 1.1% were over 60 years old. Almost 42 respondents have technical education, 48 a bachelor's or master's degree, and 5 a PhD's degree.

Around 60.1% of the interviewees work exclusively with seniors within a maximum of 3 years, demonstrating that elderly care caregiver represents a promising profession. Relating the collaborative networks area, only approximately 26% work in a collaborative environment indicating that the area is considered a challenge and not fully consolidated yet.

The summary of outcome analysis of each item is presented in the following graphs (Figure 6.11 to 6.17).

Dimensions D1:*Perceived Usefulness,* D2: *Perceived Ease of Use*, and D3:*Habit* constitute the *Technological Context* (see Figure 6.11). In general, the dimensions *Perceived Usefulness* and *Perceived Ease of Use* had a high acceptance (respectively 76,25% and 74,38% of agree and totally agree). However, *Habit* had 51.25% of acceptance. In fact, this outcome is expected since the use of technology by the elderly still represents a challenge. Although almost all participants mentioned they feel comfortable with information and communication technologies (92.1%), only 31.25% already use some type of ecosystem and related technologies for elderly care. In addition, 58.75% believe that the ECE can affect the customer's privacy. Figure 6.12 shows the *Technological Context* results. The averaged values indicate that the acceptance is high - 42.1% agree and 24.48% totally agree (total: 66.58%) against only 12.78% disagree and totally disagree.

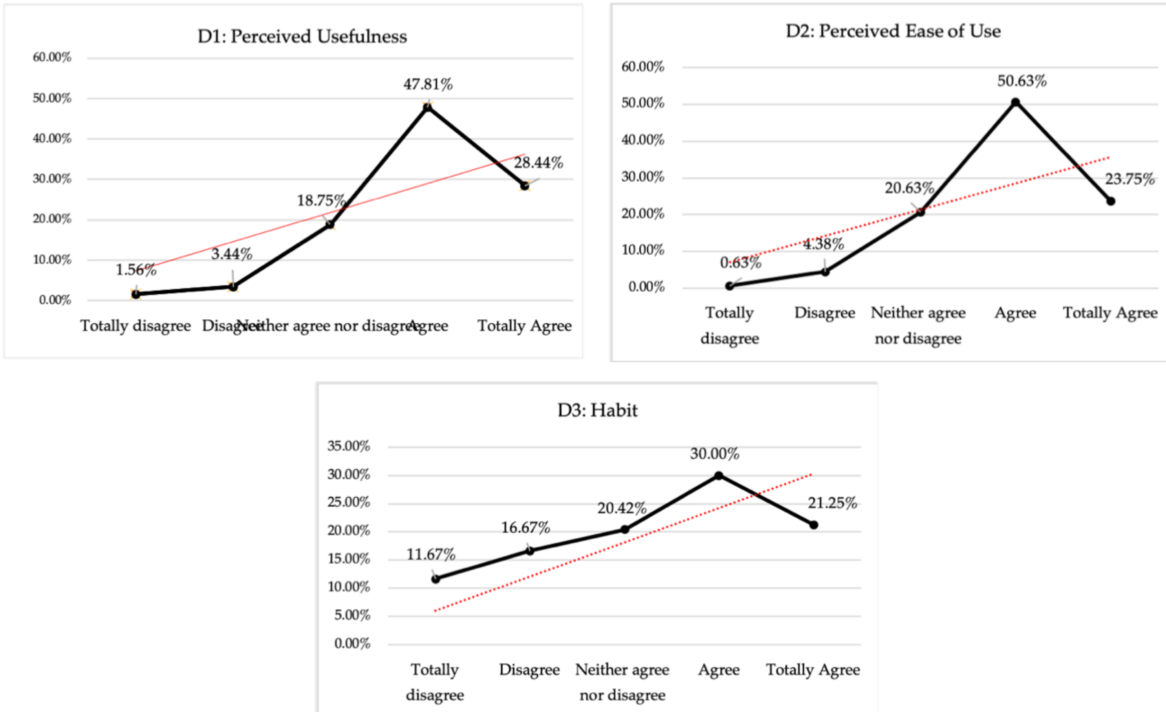


Figure 6.11: Dimensions 1, 2 and 3 and Related Results

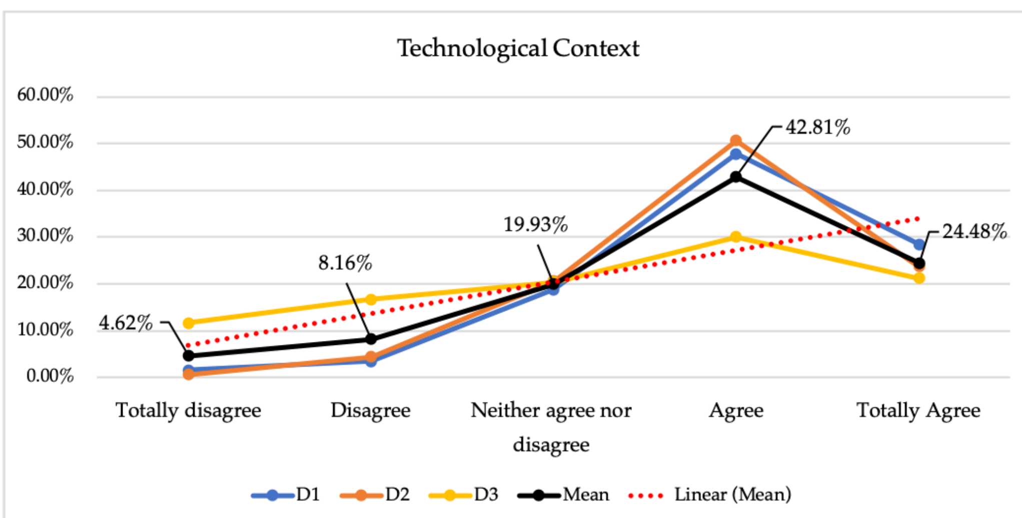


Figure 6.12: Technological Context Results

In the *Organizational Context* (see Figure 6.13), the two dimensions that were below 70% of "agree" and "totally agree" together were D4 and D5. In both, there is a high index of neither disagreement nor agreement. In *Compatibility*, an identified outline refers the absence of the use of an ecosystem to service personalization and evolution (none of the companies we visited has a system for recommending services; this task is currently a human decision).

Relating to *Social Influence*, the participants believe that the customers may not accept being monitored for fear of losing their privacy, and the ECE members may not provide complete data because they feel unsafe and fear disclosure of sensitive information to their competitors (now partners in ECE). With the large data handled by ECE, a reliable information security policy should be implemented to manage the uncertainties which might affect the security of their organization´s information over time. It is also necessary to consider individual data protection namely in accordance to GDPR rules (Voigt & Von dem Bussche, 2017). It is demanding proper investment and business adaptation for participating of the ECE. *Attitude* results represent that the ECE will have a positive impact for elderly care service provision with 75.32% of acceptance.

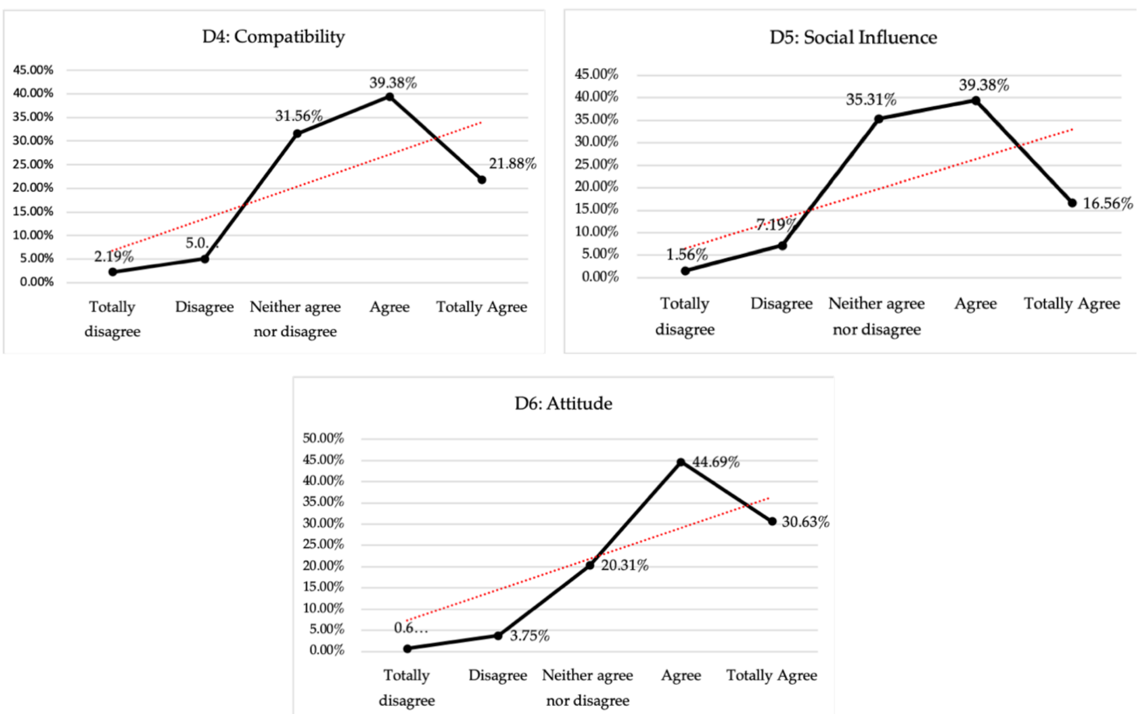


Figure 6.13: Dimensions 4, 5 and 6 and Related Mean Results

An overview of the *Organizational Context* results is shown in Figure 6.14. The averaged values indicate that the acceptance is high - 41.15% agree and 23.02% totally agree (total: 64.17%) versus only 6.77% disagree and totally disagree together.

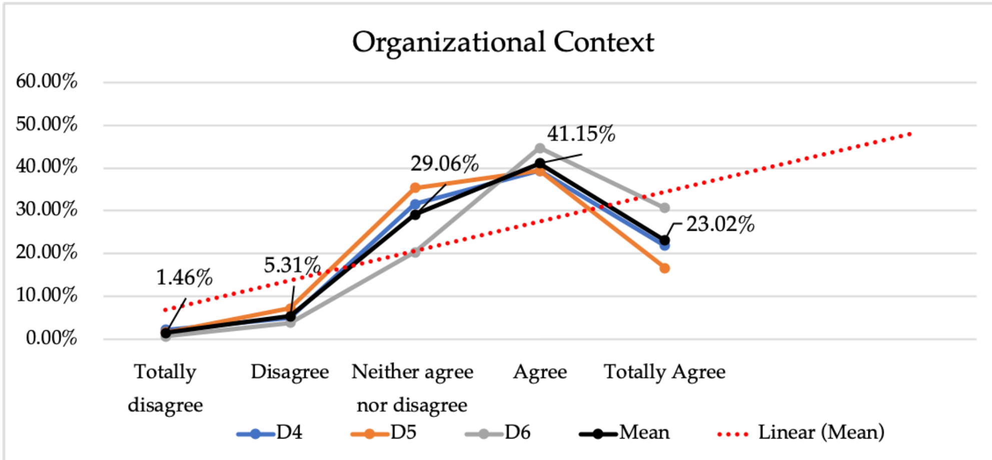


Figure 6.14: Organizational Context Results

The *Collaborative Environment* Context (see Figure 6.15) is composed of dimensions D7: *Self Efficacy* and D8: *Business Relevance*. These dimensions were only considered for those who presented some background on collaborative networks. Relating to *Self Efficacy*, the acceptation index is high (almost 80.55%). Similarly, *Business Relevance* index is very high (around 88.89%) for acceptation. Considering the *Collaborative Environment* context overview shown in Figure 6.16, the acceptance percentage is high (almost 84.72%).

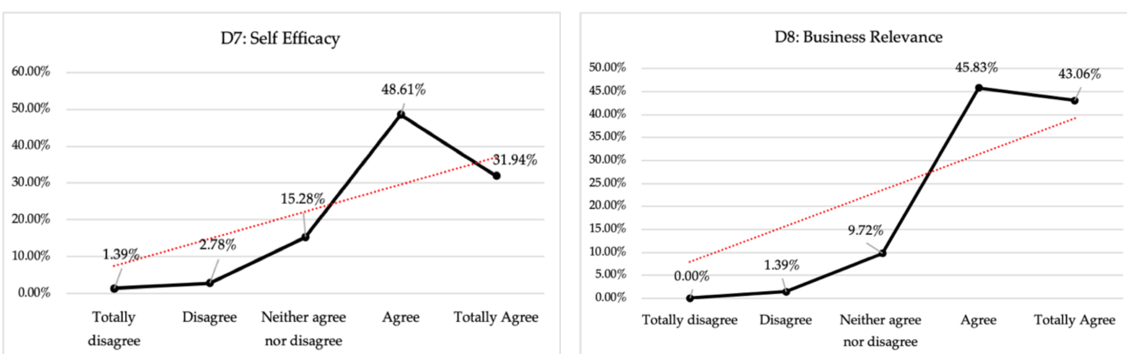


Figure 6.15: Dimensions 7 and 8 and Related Mean Results

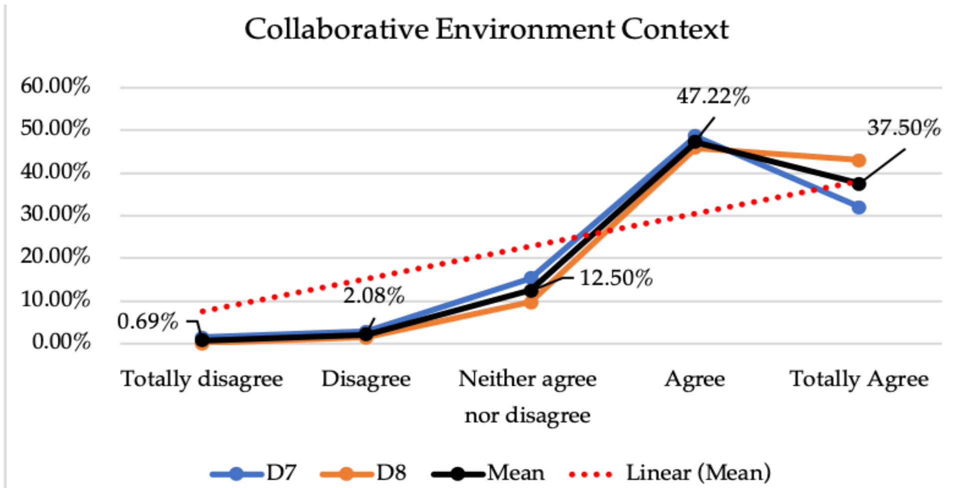
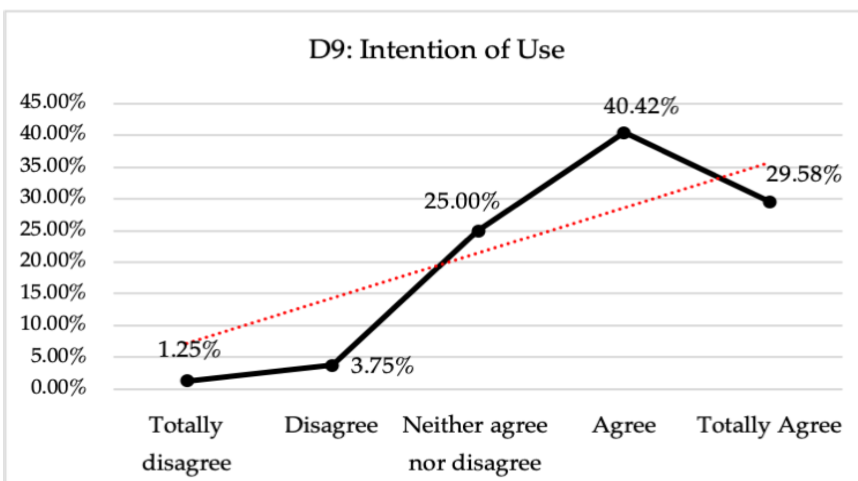


Figure 6.16: Collaborative Environment Results

The last dimension, D9: *Intention of Use* is the dependent variable in the descriptive statistics of the theoretical variables. This variable depends on all other variables previously presented to compute it. The general averaged values of *Intention of Use* questions show a high acceptance as presented in Figure 6.17. On the other hand, the question four (*The use of an ECE to monitor my customer is not intrusive and unpleasant)* had a high standard deviation, which means that there is no consensus about the issue (42% agree and 31% disagree).



	D1	D2	D3	D4	D5	D6	D7	D8	D9
Mean	3.98	3.92	3.18	3.74	3.62	4.01	4.07	4.31	3.64
SD	0.87	0.81	1.28	0.93	0,90	0.85	0.84	0.71	1.08
Correlation with D9	0.34	0.30	0.31	0.34	0.29	0.38	0.06	0.43	1.00

Figure 6.17: Intention of Use Results

6.2.6 Experiment Limitations

Although the outcome of the experiment indicates that the proposed solution is promising for the field of elderly care, we have identified some limitations in our study that have to be considered. First, the same questionnaire was used for different roles, namely staff, caregivers and managers. If we segregate the questionnaires for each role, we might get more real data per actuation area. Second, we identified that the concept of collaborative networks is often confused with the term "cooperatives" in Brazil. We are not sure if the participants that stated that they work with collaborative networks really do, since they also do not have a computer-based collaboration system. Considering that the dimensions *Self-Efficacy* and *Business Relevance* were evaluated by workers in collaborative environments, the results may not reliably reflect the reality. A third aspect to consider is that our theoretical model involves additional constructs added to the TAM methodology. It would be interesting to test this model in a future work and add other potentially important variables to improve the predictive power of the theoretical model. Finally, the technology may be a barrier to understanding the proposed concept because most caregivers do not use technologies to recommend and select a service.

6.3 Evaluation in the Research Community

As the author is a member of the Society of Collaborative Networks (SOCOLNET), the development of this research work benefited from continuous interaction with various experts and stakeholders of the SOCOLNET society. These interactions were valuable for the positive feedback on the acceptance of the underlying concepts and the contributions for the collaborative networks sustainability. Additionally, the outcomes of this Thesis were published in several international peer-reviewed conference proceedings and scientific journals (indexed in the WoS/SCI). Figure 6.18 presents the list of publications and the corresponding contributions for this work that include: one publication in an international journal, one publication in a national journal, eight publications in proceedings of international conferences with peer reviewing (including six book chapters), and two works that are still in progress (aiming a journal publication).

Furthermore, other contributions include: book editor, poster and panel presentations, and advisor on undergraduate dissertation. These activities are presented in Figure 6.19.

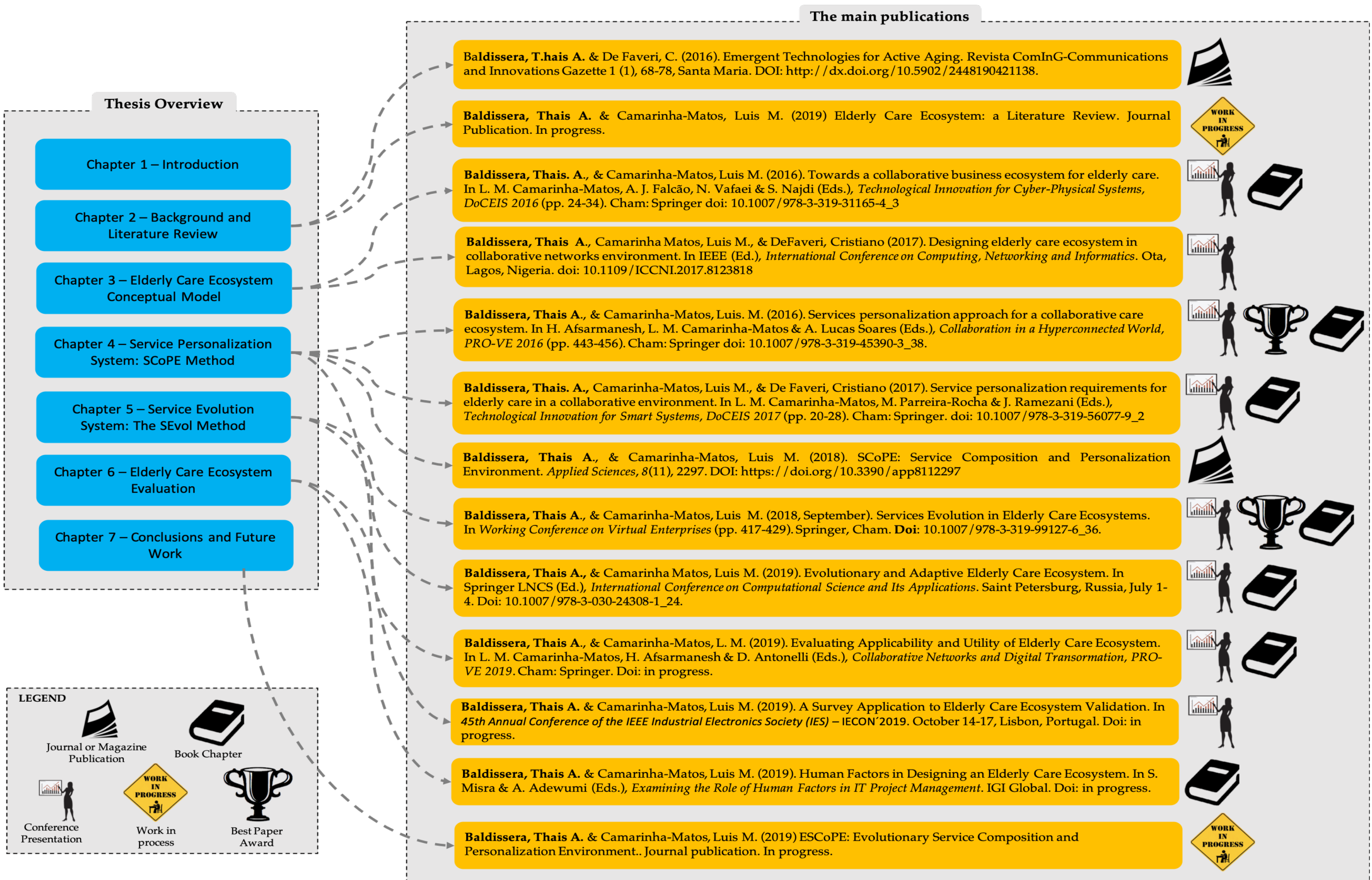


Figure 6.18: Thesis Overview and related main publications

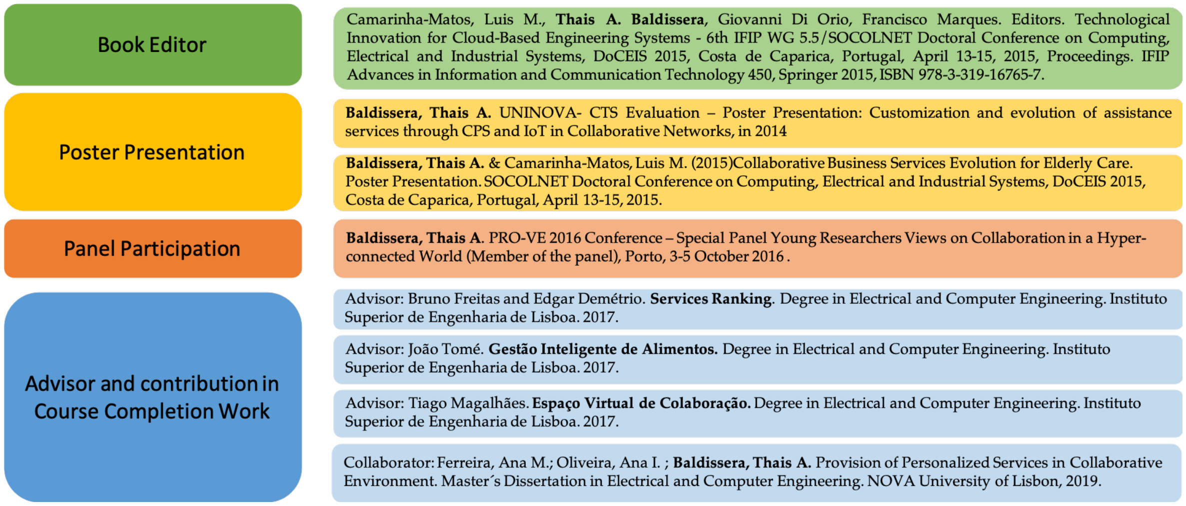


Figure 6.19: Other Contributions/activities

6.4 Summary

This chapter presented the ECE evaluation process. We applied a survey based on modified TAM considering three contexts: *Technological, Organizational* and *Collaborative environment.*

The majority of the participants responded that they work exclusively with elderly for no more than three years, which shows that the profession of elderly caregivers has been fostered as the corresponding population grows. However, dedicated elderly care technologies for service personalization and evolution are still underutilized. All participants declared to not use any kind of software system to assist them on decisions of personalization and evolution of services. This is still a fundamentally manual process. Moreover, although the participants believe the ECE can contribute to improve their business and assist their customers better, they are still reluctant to fully adopt this kind of technology without a clear methodology for transition (manual to automated) and well-defined security and privacy policies. In particular, the latter is a strong concern declared by the participants.

Due to the high-competitive market, the organizations recognize they need to improve their processes and tools to provide services that can be personalized and evolve over time. One of the concerns these organizations have shown is regarding the multiple roles the organizations can assume in a collaborative network. Organizations that seem competitors today can become partners tomorrow, form a virtual organization and expand their business. This demands well-established policies and maturity from the companies to play distinct roles in different business scenarios.

There is a perception that the concept of collaborative networks is known by the participants but using an earlier form - cooperative. Hence, the idea of collaborative network is not fully implemented. A quarter of the interviewed participants declared to know and use collaborative networks in their work. Nevertheless, it is natural to expect a certain level of skepticism when adopting new technologies like the ECE. However, the findings show the ECE had a strong acceptance in the researched community, having a positive impact in the nine dimensions considered in our survey.

7

Conclusions and Future Work

This chapter summarizes the main findings and results obtained. First a summary of the work undertaken is made, followed by corresponding findings and contributions. Finally, a number of open issues established for future work are discussed.

7.1. Summary of the work

The main research question addressed in this thesis was "how to provide personalized and evolutionary collaborative care services for elderly in an effective and reliable way?". In order to answer this research question, the following hypothesis was formulated: "Effective and reliable personalized and evolutionary services for elderly care can be provided if a suitable set of multi-provider business services is composed and integrated in the context of a collaborative network environment and supported by context awareness methods, mechanisms and systems". This dissertation responds to this challenge by presenting an innovative framework comprising methods, mechanisms, and systems designed to provide personalized and evolutionary multi-supplier care services to elderly in a collaborative network context.

A conceptual ECE framework, composed of four main structures:

- ECE Manager System ($\mathrm{ECE_{MN}}$),

- ECE Information System (ECE_{IS}),

- ECE Personalization System (ECE_{PS}), and

- ECE Evolution System (ECE_{EV})

was proposed.

The framework provides a dynamic care needs taxonomy at the base of the personalization process, representing a common "language" to identify services and needs. A number of generic profiles based on templates of customer (elderly) profile, care need profile, service profile and service provider profile, are also defined. The Service Composition Personalization Environment — SCoPE method for identifying and classifying services was proposed as part of the ECE_{PS}. SCoPE is designed to find and recommend potential solutions (providers and services) that better fit customers' care needs. Moreover, SEvol is proposed as a method to support the process of evolving a service for elderly care in a collaborative network environment. The specific model for service evolution and the solution evolution loop within ECE are detailed through a workflow diagram that considers the main ECE´s processes and their interactions.

7.2. Novel contributions

The novel contributions of this thesis include a set of concepts, models, and methods to represent and provide personalized and evolutionary services for elderly care within the scope of a collaborative network environment. The original contributions appear at four different levels, as depicted in Figure 7.7: concepts, models, methods, and tools.

- ✓ **Concepts.** A set of concepts related to personalization and evolution of services for elderly care are discussed and formally defined. By giving a formal description of the concepts, we provide base support for automated processes, including calculations such as *Closeness* and *Service Adherence*.
- ✓ **Models**. The concept of ECE is based on a computer-supported collaborative environment that allows the combination of services potentially involving multiple providers to seek better solutions for the senior's care needs. The conceptual model is presented using UML class diagrams, descriptions using

natural language, and a formalization of the model used during the service composition, personalization, and evolution processes.

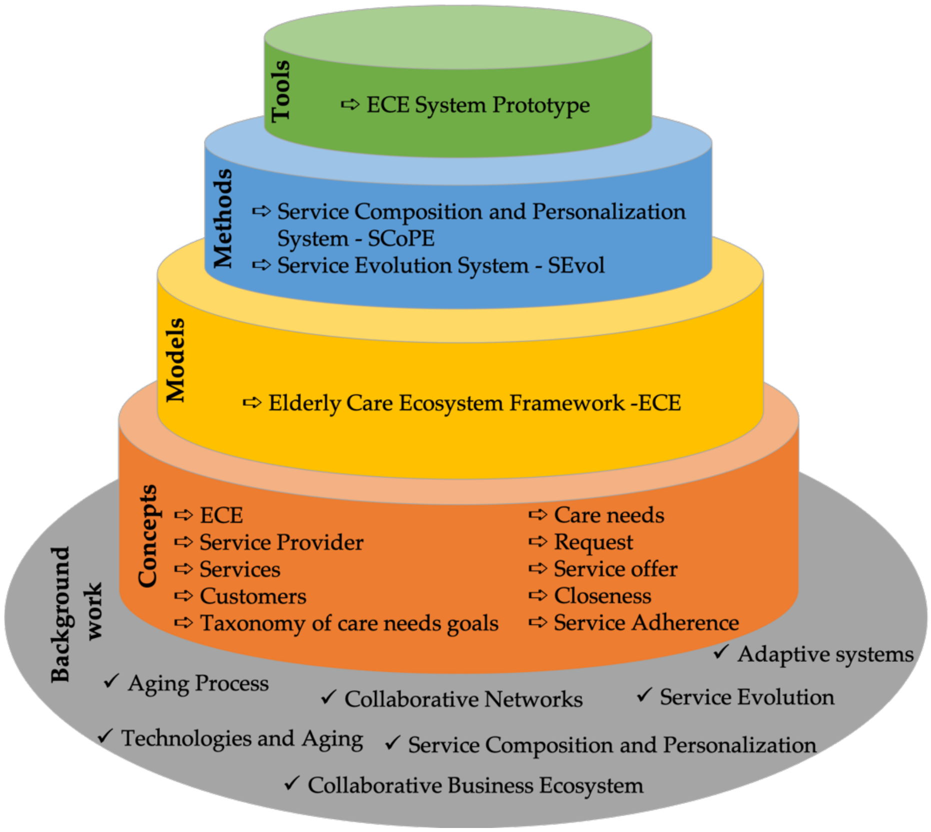


Figure 7.7. Contributions

- ✓ **Methods.** The SCoPE method is based on the match between the customer´s profile and the available {service, provider} pairs. The calculation of a service adherence index to a specific customer identifies suitable services and corresponding providers to attend him/her. SEvol is a method to build an adaptive and evolutionary system based on the MAPE-K methodology, supporting the solution evolution to cope with the new life stage in the elderly care domain. SCoPE and SEvol represent the two methods proposed in the ECE framework for service personalization and evolution respectively.
- ✓ **Tools.** A Software System was designed to support the context of decision on service provision for elderly care. A version of ECE was implemented as a prototype and fed with illustrative information to demonstrate its basic

operations (inclusion, exclusion, customer search, care needs, services, services providers) and the SCoPE and SEvol execution.

- ✓ **Background knowledge.** Tools, methods, models and innovative concepts are all grounded into a set of existing studies on collaborative networks, aging process, technologies for aging support, adaptive systems, service evolution, care service composition and personalization, and collaborative business ecosystems. Various contributions to the background knowledge (collaborative networks, technologies and aging, collaborative business ecosystem, service composition and personalization, service evolution, and adaptive system area) occurred during the course of this work. The dissemination of the results was done through publications in peer-reviewed international conference proceedings, book chapters, and journals. Also, a number of participations in panels and posters was conducted during the development of this thesis.

7.3. Evaluation

In order to validate the proposed approach, Saunders (2011) recommendations and the technology acceptance model (TAM), adapted from Davis et al. (1989), were used. For this purpose, we developed a prototype comprising a set of ECE core features to evaluate the applicability of the approach. Moreover, we conducted a survey with professional domain experts to evaluate the perceived ECE's utility.

7.4. Future directions

The outcomes of this thesis indicate that the proposed solutions are relevant in the target domain of elderly care. Nevertheless, this thesis also opens the opportunity for several new research directions, namely:

- ✓ **Taxonomy improvements**

Improving the relationship between the care needs taxonomy and the services and customer request. Mapping customer's need and potential services is one of the greatest challenges when designing personalized services in the ECE. There is a multitude of parameters that may be considered to select a set of services in the ecosystem. Services should require distinct data to cover certain needs, thus, the matching process should be flexible enough to connect both sides (customer needs and offered services). In this sense, it is necessary to identify a richer common "language" that maps them to a taxonomy of services and care needs to get more accurate results.

✓ **Service integration**

Service adaptation is challenging since many services can be dependent on each other, and there are various constraints that need to be observed before adaptating and enacting new services. There is a need to guarantee the adaptation does not interfere in other services currently under execution. Also, it is necessary to established methods to return the system to the previous state when the adaption does not achieve its goals.

✓ **Security, privacy and other non-functional requirements**

Security and privacy are one of the main concerns in modern systems. As observed by most of the participants of our survey, customers may hesitate in adopting solutions like the ECE due to security and privacy issues. In this sense, rigid security models need to be developed. We highlighted some open key aspects of service proposition requirements and challenges that should be overcome during the design and implementation of an ECE. It is not our intention to present a comprehensive list of concerns (e.g. cold start phenomenon, performance, fault tolerance, etc.). Instead, we describe concerns we understand are those more critical for designing a service recommendation feature in the context of the ECE:

- *Scalability and Performance.* As the amount of providers and customers grow, selecting services in response to new customer's state can be computationally infeasible. There is a need to optimize the searching for potential services, while keeping the recommendation list relevant for each particular customer.
- *Accuracy prediction*. Sensors data can be incomplete, due to failures on sensing devices, noise in the communication, among other factors. Under this situation, a

recommendation function demands predictive mechanisms (e.g. machine learning strategies) to keep ECE operational. Moreover, poor customer's information, or incomplete description of characteristics of the services or providers, may make the service solution to be inefficient.

- *Interoperability.* Services from different providers are required to interoperate with each other to form personalized integrated solutions. The ECE should provide support to express in more details how two providers can work together based on required and provided resources (strict interoperability principles).

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