Ana Maria Fazeres Ferreira

Licenciada em Ciências da Engenharia Eletrotécnica e de Computadores

Provision of Personalized Services in Collaborative Environment

Dissertação para obtenção do Grau de Mestre em Engenharia Eletrotécnica e de Computadores

Orientador: Professora Doutora Ana Inês da Silva Oliveira, Professora Auxiliar Convidada da Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa

Júri:

Presidente: Prof. Doutor André Teixeira Bento Damas Mora – FCT/UNL

Arguente: Prof. Doutora Filipa Alexandra Moreira Ferrada – FCT/UNL

Vogal: Prof. Doutora Ana Inês da Silva Oliveira – FCT/UNL

FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

Março, 2019

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To my 7 wonderful. For everything…

Acknowledgements

I finally see the finish line. But I have never been alone. And because you helped me to get here, I want to recognize your importance.

- To Professor Ana Inês da Silva Oliveira for accepting to be my supervisor and for giving me a boost of strength to carry on. Without her, this work wouldn't have been possible, and who knows if I would be here

- To Engineer Thais Andrea Baldissera, for the enthusiastic way she introduced me and got me into the world of "collaborative business ecosystem for elderly care"

- To Rute Xavier, for the always quick answers, helping in and solving questions that seemed to have no possible answer

- To Pedro, who spent so many hours with me, thinking out loud, arguing, writing and erasing. Together we built and we celebrated all the little victories. Until we got here

- To Edna, Sara, and Vasco, but also to my other faculty colleagues who, throughout these years made a difference in my life

- To the group that have watched me grow up and that has been so supportive in this entire journey – David, Francisca, Gonçalo, Inês, Joana, Mariana, Paulinha, Rita, Rosário, Sara, Tiago

- To the Bounce gang, who welcomed me so well and who have been fundamental for my mental health

- To Rita, for all the times we talked, shared, for the understanding and for your availability

- To Sara, who never once doubted me and, even at a distance, always told me I would be able to overcome everything

- To my father, for teaching me to love sciences

- To my brother Pedro, for teaching me to love Math

- To my mother, for teaching me to love people

- To my brother João, for helping me to think "out of the box"

- To Sónia, who knows me almost since ever, who, for me, has given up of so many moments that could have been only hers, and who is always there, in constant support

- To Rita, for the confidence she had in me since day 1

- To Tiago, who has been walking this path with me, on and off the college. Together we have been growing and building. Together we have been fighting. And discovering that together we are, indeed, much stronger

- To the seven of you, because you are my rocks. Without you, nothing of these would have been possible.

Thank you very much!

Abstract

We have been witnessing in the past few years a change in the social paradigm, moving, in just a few dozen years, from a population that used to live less years into one that has increased greatly its life expectancy. This change will imply that the reality of the existing services is also changing, with a much deeper attention being drawn into elderly and their needs.

Because each person is unique and has specific needs and desires, it is very difficult that a single service or service provider can provide this solution in a satisfying manner. So, concepts like cooperation and collaboration, as well as service ecosystems become very important in the answer to the new social needs, becoming possible to provide adequate services to every elderly.

The present work is integrated in a PhD research work, in which an ecosystem was conceptualized. That ecosystem has as inputs information regarding elderly people, their care needs, services they require, and the service providers. This ecosystem is managed by an ecosystem manager whose responsibility is to gather the information from the different sources and later, upon request, to run the algorithm to find the most appropriate solution for an elderly. This work's goal is to develop an algorithm – named Service Composition and Personalization Environment (SCoPE) - which will evaluate the elderly request and the information that exists regarding the different services and service providers and try to provide several options to that elderly, according to predefined criteria. This algorithm is the ecosystem final part.

The answers provided by the ecosystem's algorithm depend, at each moment, on the information that the ecosystem has. This means that, in case the elderly changes its needs, or in case of the appearance of new services or service providers, the algorithm's answer may be different. Not only that but also the solutions provided by the algorithm are not meant to be taken as definitive answers for the elderly but as suggestions, so that the elderly may make an informed decision.

In conclusion, the developed work demonstrates that the proposed algorithm can provide consistent results to the ecosystem.

Key words: Cooperation, Collaboration, Ecosystem, Algorithm

Resumo

Nos últimos anos, tem-se vindo a assistir a uma mudança no paradigma social, já que se passou, no espaço de algumas dezenas de anos, de uma população que vivia menos anos para uma população que aumentou em muito a sua esperança média de vida. Esta mudança implica que a realidade dos serviços existentes está também a mudar, com a consequente redobrada atenção para com os idosos e as suas necessidades.

Porque cada pessoa é única e tem necessidades e desejos específicos, será muito difícil que com um único serviço ou fornecedor de serviços se consiga dar uma resposta de forma satisfatória. Assim, conceitos como cooperação e colaboração, bem como ecossistema de serviços, tornam-se fundamentais na resposta às novas necessidades sociais, permitindo o fornecimento de serviços adequados a cada pessoa idosa.

Este trabalho está integrado num trabalho de investigação no âmbito de uma dissertação de doutoramento em que foi conceptualizado um ecossistema. Esse ecossistema é alimentado por informação relativa a pessoas idosos e suas necessidades, serviços que necessitam e fornecedores de serviços. Este ecossistema é gerido por um administrador do ecossistema cuja responsabilidade é reunir a informação das diferentes fontes e posteriormente, após solicitação, correr o algoritmo para obter as soluções mais apropriadas para um idoso. O objetivo deste trabalho é desenvolver um algoritmo, denominado SCoPE (Service Composition and Personalization Environment) – e que irá avaliar o pedido do idoso bem como a informação existente relativa aos diferentes serviços e fornecedores para tentar fornecer hipóteses que satisfaçam o idoso, de acordo com critérios pré-definidos. Este algoritmo é a etapa final do ecossistema.

As respostas que o algoritmo do ecossistema vai gerar dependem, em cada momento, da informação de que o mesmo dispõe. Isto significa que, caso o utilizador mude as suas necessidades, ou caso surjam novos serviços ou fornecedores de serviço, a resposta que o ecossistema dá pode ser diferente. Para além disso, as soluções dadas pelo ecossistema após correr o algoritmo não pretendem ser encaradas como respostas definitivas, mas sim como sugestões para o utilizador, para que este possa tomar uma decisão o mais informada possível.

Concluindo, o trabalho desenvolvido demonstra que o algoritmo proposto consegue obter resultados consistentes para utilização pelo ecossistema.

Palavras – chave: Cooperação, Colaboração, Ecossistema, Algoritmo

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List of Acronyms

AD – Adherence

CAT – Care Need Taxonomy

CL – Closeness

CN – Collaborative Networks

CO – Service Coverage Level

ECE – Elderly Care Ecosystem

MVC – Model View Controller

PA – Partial Adherence

PVC – Professional Virtual Community

RL – Customer Care Needs Relevance

SCoPE – Service Composition and Personalization Process in Collaborative Environment

SP – Service Provider

VBE – Virtual Organization Breeding Environment

VO – Virtual Organization

1

Introduction

1.1 Motivation

The world in which we live in has been changing over the past years and certainly this will continue to happen. Nowadays, the world population has reached several billion and what we have been witnessing is a growth in the number of elderly population and a decrease in young people. This means that the reality we knew from years ago in which everything was created with a purpose of being used by the youth, is now shifting into a new reality where elderly population play a centre role in social life.

Regarding that, several concepts need to be addressed such as the differences between cooperation and collaboration, and the definition of the concept of collaborative networks that aim to minimize the difficulties that collaboration between different entities entail. Moreover, the new focus for services that address this new social reality will force them to provide ways for elderly to be thought about as more than just an old person but as someone who wants to remain active for longer. Finally, because every person has its own specific needs and desires, a way for gathering information regarding different companies, in order to allow elderly to make a choice of services that are customized to their needs, must be found.

This thesis' goal is to support in providing an answer to the question "*How to provide personalized collaborative care services for elderly in an effective and reliable way?*" as posed by Baldissera et al. (2017), developing an approach to support an algorithm that will be integrated it into an ecosystem, which will gather the information from elderly citizens and different service providers in order to give the most appropriate answer to the elderly requests.

This ecosystem will be managed by an Ecosystem Manager, who will be responsible for gathering the information from different inputs, running the algorithm and using it to provide an answer to an elderly request.

1.2 Research Context

Two hundred years ago there were less than one billion human beings in the world. Today, the UN calculations show that we are already more than 7 billion (Roser & Ortiz-Ospina, 2017). This is the reality the world is facing, and its evolution has been, throughout time, studied so that we know that the results are both concerning and, at the same time, revealing.

Many animal species' population has been studied, so it is no surprise that the same has been happening for the human world population with data records that go back, at least, until the 1950's. The results of those studies are presented in a chart called the demographic pyramid, which intends to demonstrate the distribution of the population by gender and age gap (Weeks, 2015).

Due to numerous aspects, like wars, famine or prosper times, the demographic pyramid of the world usually varies in every year. However, when we analyse these charts, as far as recent years are concerned, it can be pointed out a clear tendency for the younger population to decrease and the elder population to grow. That new reality needs to be addressed, since it seems obvious that the needs children have are different than the needs of the elderly. More recently, that can be explained as a result of access to more and better food and water, and also because of the increase in knowledge in every area that is relevant to the human life, from medicine to technical aspects.

As it can be seen in Figures 1.1, 1.2 and 1.3, the demographic pyramid of the world has been revealing a tendency on one hand of the younger population to decrease and, on the other hand, for the elder population to increase.

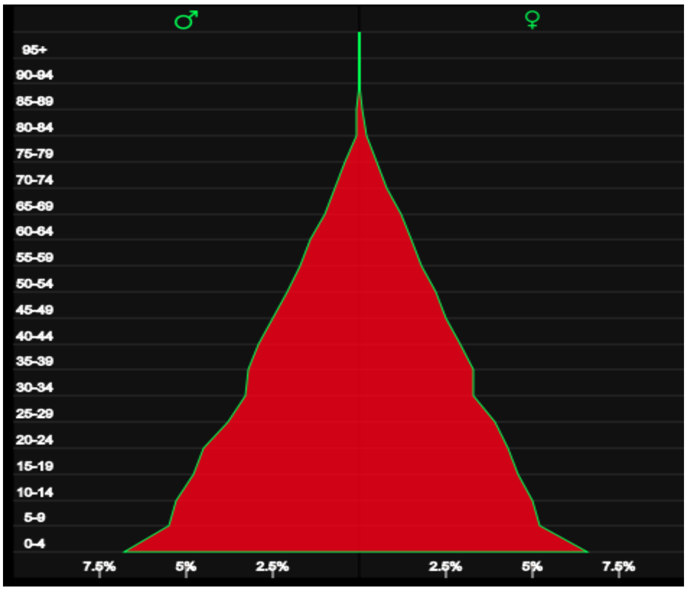


Figure 1. 1 - Demographic pyramid of the world in 1950 ("World Population Pyramid," 2019)

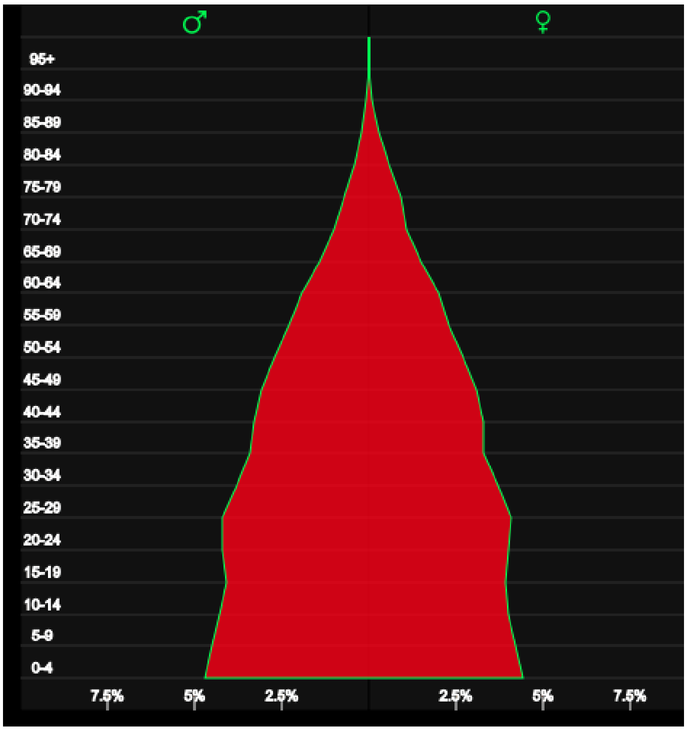


Figure 1. 2 - Demographic pyramid of the world in 2015 ("World Population Pyramid," 2019)

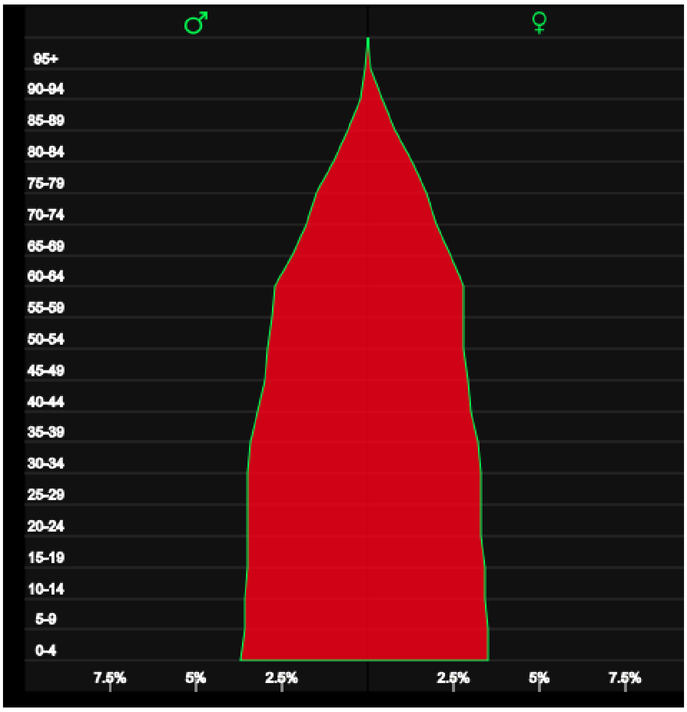


Figure 1. 3 - Demographic pyramid of the world in 2050 - prediction ("World Population Pyramid," 2019)

Moreover, since a graphic using percentages is only able to reveal tendency's, rather than producing real, measurable results, it is also shown a different pyramid that gathers the result of the population total's, and also its prediction for 2100, as illustrated in Figure 1.4.

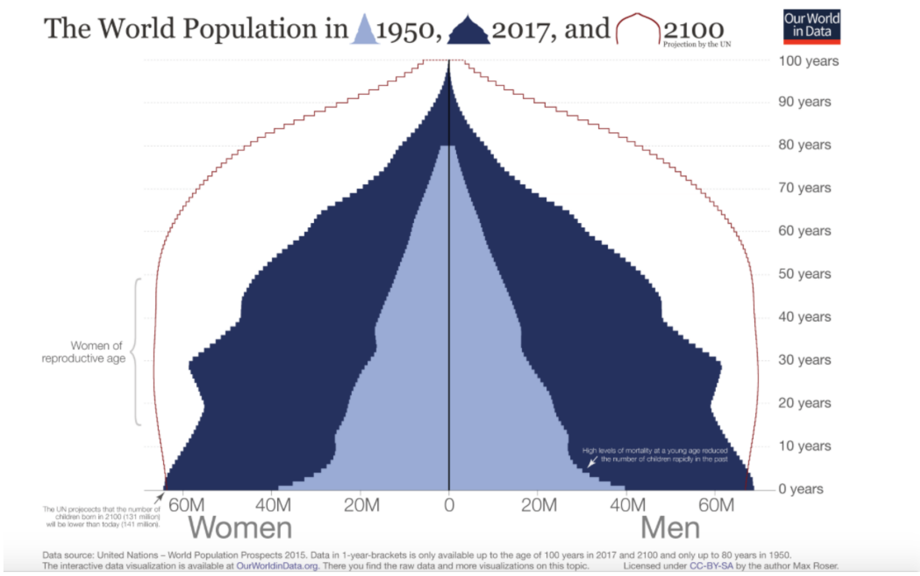


Figure 1. 4 - The World Population in 1950, 2017 and 2100 (Roser & Ortiz-Ospina, 2017)

This results in different characteristics of the general population in the overall and in having to address different needs that will become more focused on the elderly and less on the young people, as it was a reality about sixty years ago.

It must also be noted that this increase in population of elderly groups and decrease in the younger groups does not translate in a decrease of world population, as demonstrated in Figure 1.5, because the truth is that the numbers keep growing, even though the rate of growth has been decreasing, it is likely that the population will eventually start to decrease (Figure 1.6).

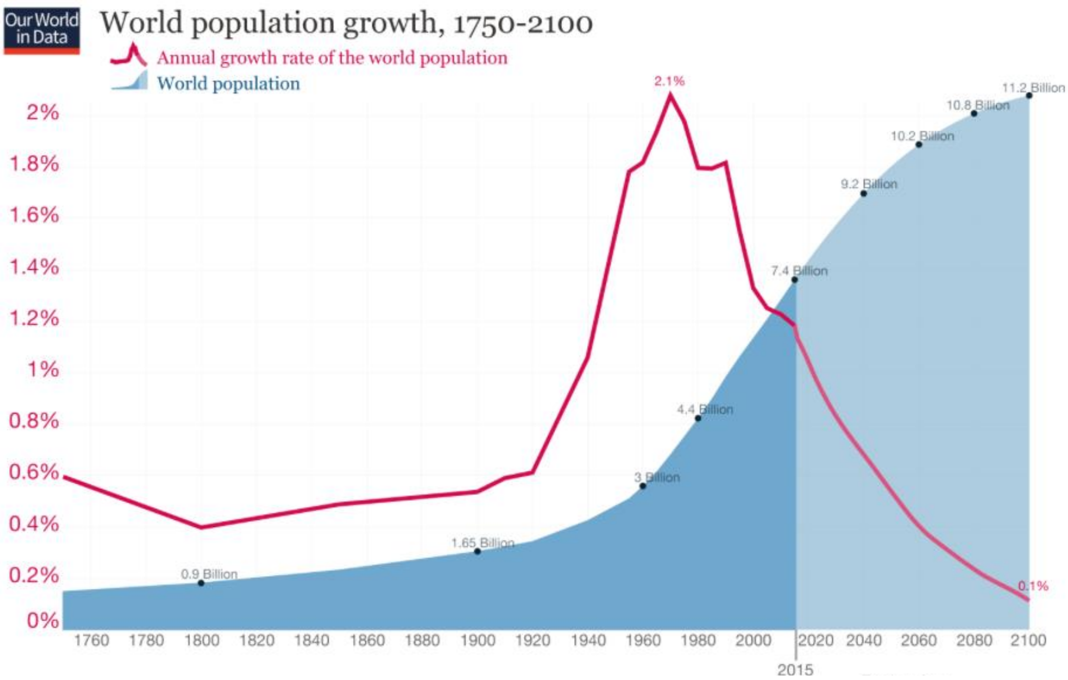


Figure 1. 5 - World Population growth 1750-2100 (Roser & Ortiz-Ospina, 2017)

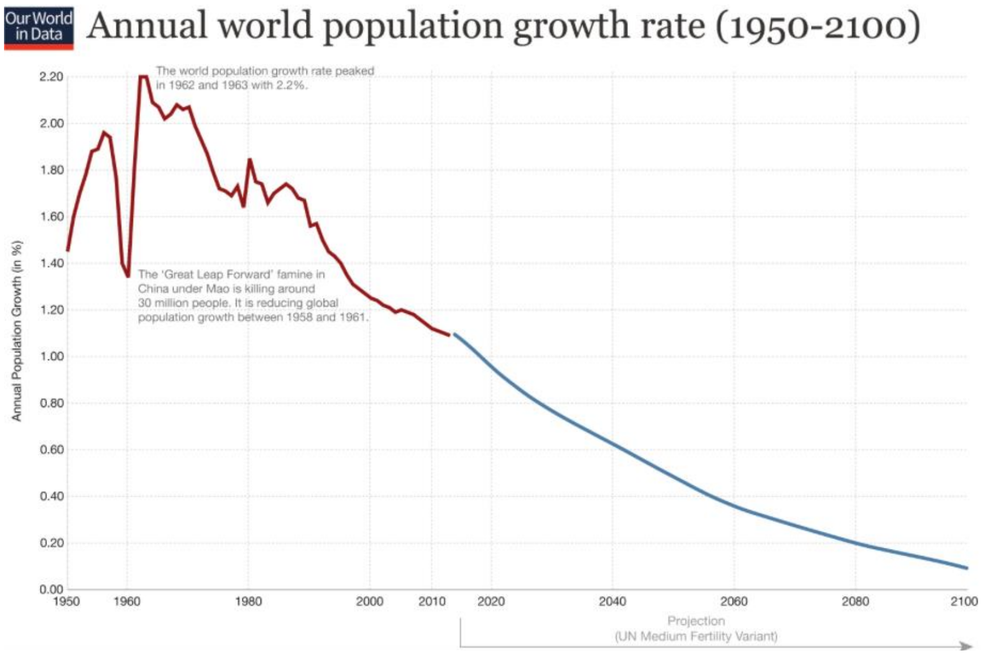


Figure 1. 6 - Annual world population growth rate (1950-2100) (Roser & Ortiz-Ospina, 2017)

This means that there will be each time more elderly people, and their specificities must be studied so that they can be better taken care of.

The increasing demographic shift associated to elderly population represents a remarkable fact in the recent history of humanity (Baldissera & Camarinha-Matos, 2018b). From 1980 until 2050, the number of people above 60 years old in the entire world are expected to grow by roughly 300% (Figure 1.7), reaching around 2000 million by 2050.

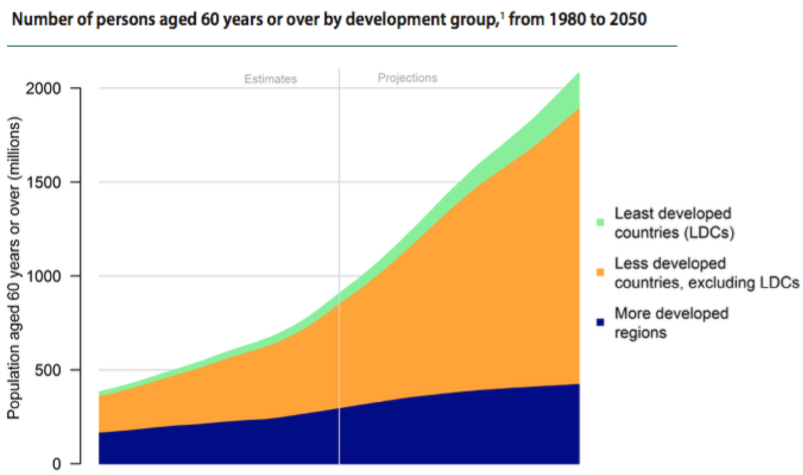


Figure 1. 7 - Number of persons with age equal or above 60 years by development group from 1980 to 2050 (United Nations & Department of Economic and Social Affairs Population Division, 2017)

With aging, additional care needs are required to preserve seniors healthy and within the standards they expect, in order to maintain their high life quality. One of two things may happen when dealing with the aging process. On the one hand, the most common way to deal with the demands and challenges of the aging process results in the elderly having to move from their home to a close relative's home (typically a son or a daughter). This results in a severe burden on relatives, not only economically but also because it normally means they will have to change their daily routines. Alternatively, on the other hand those who live by themselves often require caregivers to support them in even simple daily needs. A different person may require different particular care services according to his/her life situation. Furthermore, elderly people usually show more than one care need, as the aging process typically carries several limitations (Baldissera, Camarinha-Matos & De Faveri, 2017).

In this way, characterizing a person as elderly goes beyond the utilization of age as a determinant factor (Baldissera & Camarinha-Matos, 2018b) because, in fact, singular aging process elements such as living settings, individual capacities and abilities, contribute to describing an elderly person. Every elderly individual may require particular services (e.g. care and assistance) to his/her life context. As a result, a specific care service might be consummately sufficient for an individual and very futile for another.

Therefore, typically, no single service can fully cover the care needs of an individual and this situation suggests the need for service composition (sometimes involving several service providers). Nevertheless, the problem of selecting services and their service providers, composing a collaborative network for service delivery, is not a simple task.

There are already some social networks for seniors that try to help them in their specific needs, like the ones in Table 1.1.

Table 1. 1 –Examples of Social Networks for Seniors (Baldissera & Camarinha-Matos, 2018b. Adapted)

Name	Website
Too Young to Retire	www.2young2retire.com
American Association of Retired Persons	www.aarp.org
Silver Surfers	www.silversurfers.com
60Plus	www.60plus.org

Despite being helpful, those social networks are still incomplete since, for example, they lack the possibility to connect with service providers that the elderly would need.

Moreover, there are several elderly's services companies. The problem is that, in general, it works like this: something happens – an elderly fell, for instance – and he and his family need help right away. By chance, an acquaintance of one member of the family knows or has heard something about a company that provides elderly's services. The family contacts the company and the collaborator informs that they have a fixed service, with fixed schedules and fixed prices. The elderly and his family have to accept, although the service is not exactly what the elderly needs, because they don't have any other option and having a little help is better than having no help at all. In other words, it's necessary to find a way of join the different services and service providers available, integrate them, when necessary and to facilitate the search of the services that a specific elderly may need. And it's here where the SCoPE will make the difference, allowing exactly this.

With that in mind, this work will extend the work developed by Baldissera et al. (2017), and try to find an answer to the question "*How to provide personalized collaborative care services for elderly in an effective and reliable way?*"

1.3 Thesis' goal

The goal of this thesis is to provide an answer to the mentioned question by developing a support system to an ecosystem that will have as input information from different elderly people who have specific needs and requests, and from different service providers who will try to provide the most appropriate answers to those demands. Afterwards the ecosystem will have an algorithm that will, according to different criteria, provide possible solutions to the elderly who will, in turn, choose.

Since it has long been proven that a combined effort is likely to produce better results than an individual one, the main question that is in the origin of the present work will be approached based on the schematic of Figure 1.8.

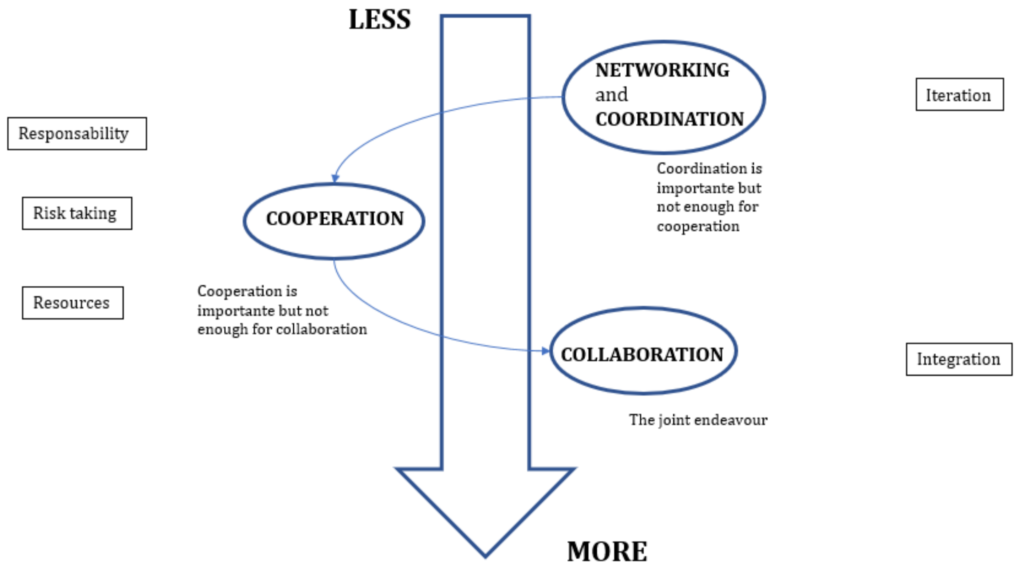


Figure 1. 8 - Networking basic concepts (Baldissera et al., 2017. Adapted)

To tackle the problem of being possible to provide the elderly the most appropriate solution that may cover its entire needs, which are different from one person to another, it will be used a Collaborative Network (CN). “A CN is an alliance constituted by 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 computer network” (Camarinha-Matos & Afsarmanesh, 2008a).

To better understand in depth a CN, there are several concepts that must be known and understood. Camarinha-Matos & Afsarmanesh (2006), define some of the most important concepts in the area of Collaborative Networks, such as Networking (and

Coordinated networking), cooperation and collaboration. Networking is what happens when two entities communicate towards a joint goal, cooperation takes place when two entities are working for a common goal, but they only know their part of the responsibilities. Finally, collaboration happens when there is full disclosure between two entities working for a similar objective.

The growth in complexity and depth of these different concepts can be seen in Figure 1.9.

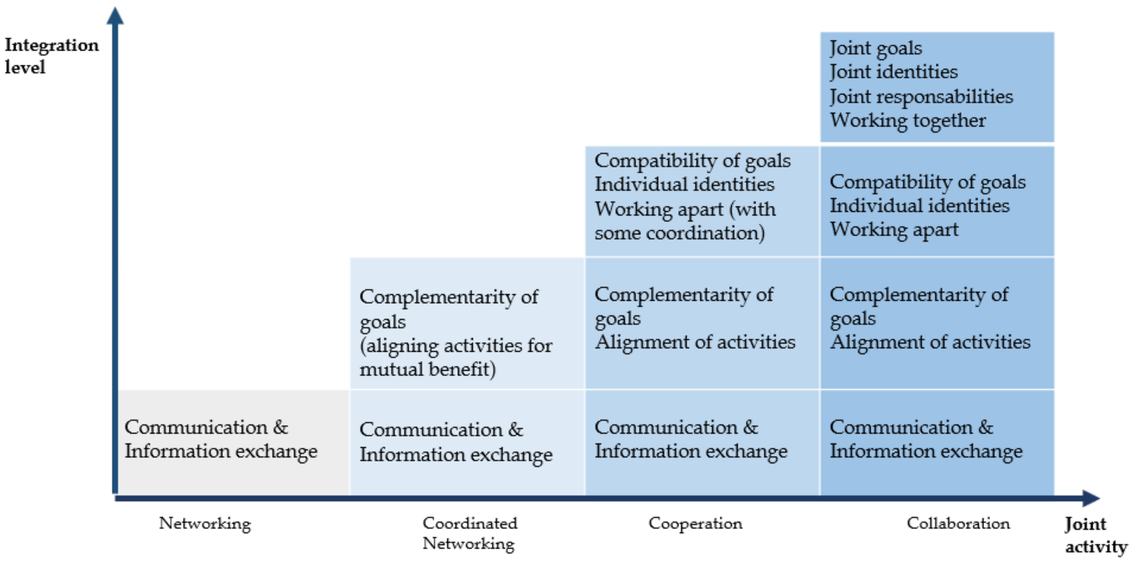


Figure 1. 9 - Examples of joint endeavour (Camarinha-Matos & Afsarmanesh, 2008c. Adapted)

An ECE shall include a number of elements, namely the seniors (customers) and their care needs, services and service provider entities, among others (Baldissera et al., 2017). An ECE characterization can thus be performed according to the following focus areas: (a) customer, (b) customer's care needs, (c) care services and (d) service providers, considering the specificity of each case, because one person may have one or multiple needs or one company may perform several services to a customer.

Regarding the focus on the customer side, one has to take into account that the personalization of a particular service will accomplish its goals better if the user's profile has more information. To build a customer profile, information such as its geographical area, life style, independent living situation and special conditions will be required to be aware of (Baldissera et al., 2017).

Considering the customer's care needs, they can be divided according to their Taxonomy (CAT). This means they can be sorted in different areas, since they can be social ones, like needing a ride to go meet friends, they can have health needs like needing someone to remind them to take pills or simply the need may be feeling useful, contributing to the society in general.

The care services and service providers are connected since one of them depends upon the other. With that in mind, the service will need a full description (similarly to the customer) and the service provider will need to have defined some characteristics to help the users understand their scope.

The ECE will be implemented using Laravel. Laravel is a framework intended for web app development.

1.4 Outline / Structure

From this point on, the present thesis will follow the following structure:

Chapter 2 – Background / Literature Review: a review on all the important concepts to approach these subjects, such as the difference between cooperation and collaboration, the definition of collaborative networks and ecosystem.

Chapter 3 – Logical Architecture: a theoretical explanation of the ecosystem will be provided, pointing out the its possibilities.

Chapter 4 – Implementation Structure: all the options from the ecosystem will be explored in detail, providing images of the different possibilities that the ecosystem manager will have.

Chapter 5 – Validation: in this chapter the scenarios used to test the Ecosystem will be thoroughly explained and some images from the Ecosystem usage will be showed.

Chapter 6 – Conclusion and future developments: in the thesis' final chapter, the conclusions regarding the possibilities of the Ecosystem will be drawn and some suggestions regarding future work lines will be made.

2

Background and Literature Review

2.1 Conceptual Basis

Nature has taught us for a long time that most of the things can present better results if they are done in a group. Weather we are talking about small animals who rely on being on a group to have a better chance for survival or talking about big predators who will take advantage of the numbers game in order to hunt their preys, the importance of being in a group has seen many different applications throughout time. The idea behind it is the fact that as a group they can take advantage of each other's best features, in order to achieve the best possible results.

Much like it happens in nature, the same can be seen in any business area since usually each company focus on its own area of expertise and together they produce the best possible product. Regardless of the context, there are several concepts that appear in every area of study's when we talk about group behaviour such as networking, coordinated networking, cooperation and collaboration (den Hartigh & Tol, 2008). For that reason, it is fundamental to be able to fully understand these terms so that they will not be confused.

2.2 Networking, cooperation and collaboration

Networking is a process that involves communication and information exchange for mutual profit (Camarinha-Matos, 2016b). A good example of networking would be found in a blog regarding a product, for example, since everyone will share information about the experience (and eventually benefit from one another) but at the same time it is not mandatory that there is a common goal for it. Coordinated networking is different from only networking since besides exchanging information, it involves aligning/altering activities so that more efficient results are achieved. Coordination which may be understood as the act of working well together, is fundamental in collaboration (Camarinha-Matos, 2016b). An example of coordinated networking can be found in gasoline and diesel selling companies when they adjust the timing of price exchanges so that its impact is not felt by them, like it would happen if only a few of them exchanged the price.

For achieving compatible goals, cooperation presupposes information exchange and adjustments of activities, and also sharing resources. Cooperation is achieved by division of some tasks among participants (Camarinha-Matos, 2016b). A traditional supply chain, based on client-supplier relationships and predefined roles in the value chain, is an example of a cooperative process among its constituents, like it is shown in Figure 2.1.

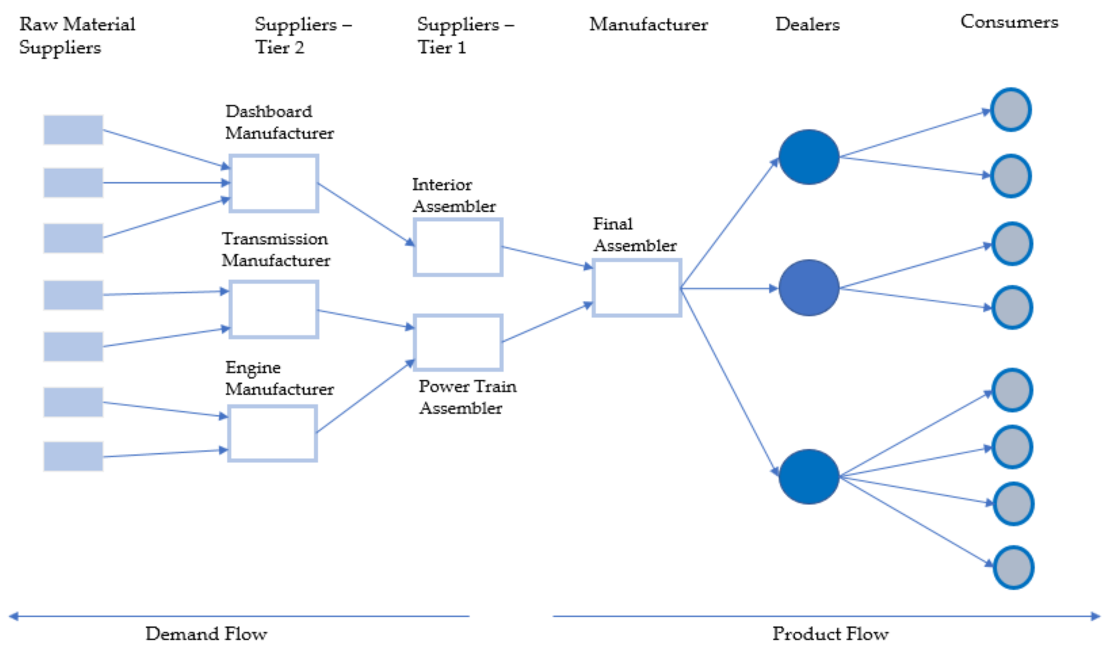


Figure 2. 1 - Classical Supply Chain (Camarinha-Matos, 2016a. Adapted)

Collaboration is a process in which, by working together, entities share information, resources and responsibilities, but also risks and rewards, expanding their capabilities. Collaboration implies time and effort and involves mutual engagement of participants. If desired, it may give the image of a joint identity (Camarinha-Matos & Afsarmanesh, 2008b). A collaboration process happens, for instance, in concurrent engineering, when a team of experts jointly develops a new product (den Hartigh & Tol, 2008). Because of its specificity, collaboration demands some criteria to be met, namely, to talk about collaboration there should exist: a purpose; parts mutually agree to collaborate; parts keep a model of each other's capabilities; share a goal and keep some common vision during the process (den Hartigh & Tol, 2008).

Also, as a process, collaboration requires setting a number of generic steps (Giesen, 2002, Camarinha-Matos et al., 2007, Oliveira, Camarinha-Matos & Pouly, 2008):

- Identify parts and bring them together;
- Define the scope of the collaboration and define desired outcomes;
- Define the structure of the collaboration in terms of leadership, roles, responsibilities, ownership, communication means and process, decision making, access to resources, scheduling and milestones;
- Define the policies, for example, handling disagreements/conflicts, accountability, rewards and recognition and ownership of generated assets;
- Define the evaluation/assessment measures, mechanisms and process;
- Identify risks and plan contingency measures;
- Establish commitment to collaborate.

It is also frequent in this field of study to contrast the term collaboration with competition. History tells us that competition is a very capable basic scheme for fighting for survival, for instance, when there is sparse of resources. With that in mind, the formation of cooperation and collaboration alliances has emerged to allow more efficient competition against other entities or groups (den Hartigh & Tol, 2008).

Despite these definitions, the distinction between collaboration and cooperation is not always obvious; in fact, in a collaborative network, there are some periods of time with intense collaboration, intercalated with others of partners' independent work (Camarinha-Matos & Afsarmanesh, 2008b).

As we walk the path starting in networking and going all the way through to collaboration, we increase the amounts of common goal-oriented risk taking, commitment and resources that participants must invest into the joint endeavour. So, in this work, we will focus on collaborative networks.

2.3 Collaborative networks

In Collaborative Networks there is a shared belief that together the network members can accomplish goals that would not be possible or would have a higher cost if attempted by them individually (Camarinha-Matos & Afsarmanesh, 2005). Thus, an agreement between various entities, such as organizations and people, that are broadly autonomous, geographically dispersed and heterogeneous in many aspects, but that collaborate to accomplish equal or congruent goals and whose communications are sustained by computer network constitute a collaborative network (Camarinha-Matos & Afsarmanesh, 2006; Oliveira, Camarinha-Matos & Pouly, 2010).

In broad terms, there can be many differences in collaborative networks, like it is demonstrated in Figure 2.2.

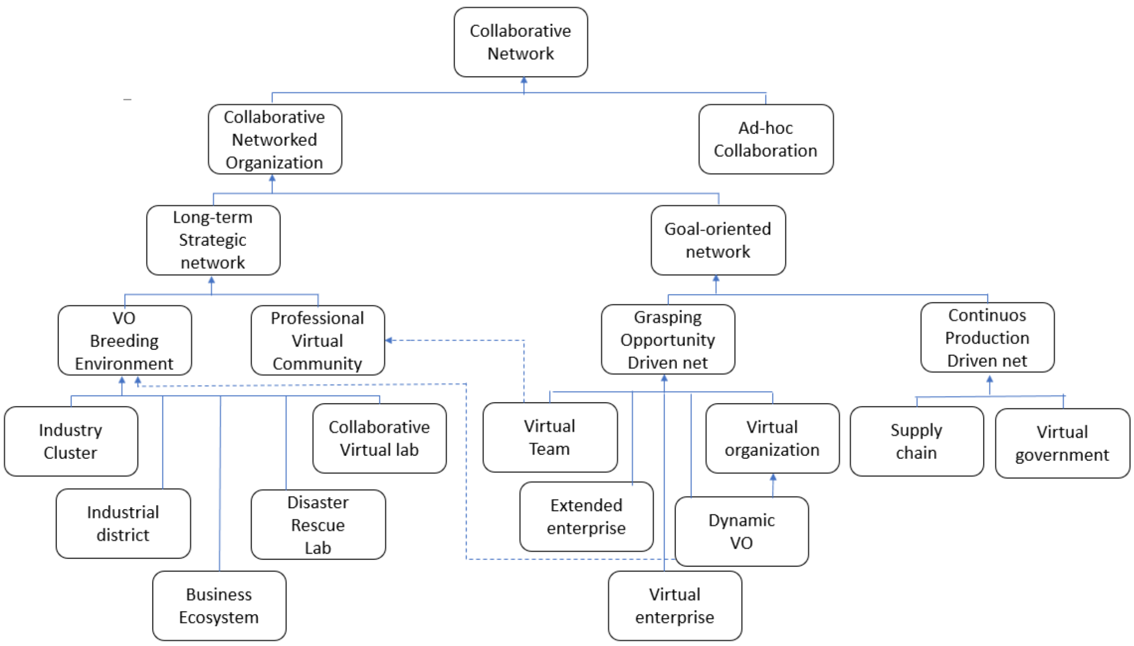


Figure 2. 2 - Classes of collaborative networks - examples (Camarinha-Matos & Afsarmanesh, 2008a)

Collaborative Networks can be divided in Ad-hoc Collaboration (more specific) or Collaborative Network Organization (Camarinha-Matos & Afsarmanesh, 2008a). The latter ones can be built as goal-oriented networks, where intense collaboration takes place or as Long-term strategic networks, where cooperation is practiced among their members. Goal-oriented networks may be faced as activities of continuous production provision or as grasping an opportunity (Camarinha-Matos & Afsarmanesh, 2008b). Its examples include, among others, supply chains, virtual enterprise and virtual team.

Networks conducted by continuous manufacturing activities, as supply chains, are a durable network of enterprises, where all partners have defined roles in the manufacturing value chain, going from the product design and the acquirement of raw materials up until the final product (Camarinha-Matos & Afsarmanesh, 2008b). Networks driven by the goal of taking advantage of a specific opportunity, as virtual enterprises, represent a brief alliance of companies that come together to share abilities or core expertise and resources with the purpose of better respond to business opportunities and whose cooperation is supported by computer networks (Camarinha-Matos & Afsarmanesh, 2008b).Virtual teams are similar to virtual enterprises but formed by humans, instead of organizations.

Examples of Collaborative Network Organizations that come from a long-term strategic network are Virtual Organization (VO) Breeding Environment (VBE) and a Professional Virtual Community (PVC). A set of enterprises and their related supporting institutions, respecting a base long-term cooperation agreement and accepting of common operating principles and infrastructures with the major aim of rising their readiness towards accelerated composition of brief alliances for collaboration in potential virtual organizations, constitutes a VBE (Camarinha-Matos & Afsarmanesh, 2006).

There are also several different types of VBE, such as Industry Cluster, Industrial district and Business Ecosystem. Industrial Clusters are one of the primordial types of VO breeding environments, consisting of a association of different enterprises, commonly based in the same geographic region and operating in a common business sector, that keeps some connections with each other so that they can increase their general quality in the larger area (Paytas, Gradeck & Andrews, 2004). Industrial district is similar to the concept of Industry cluster with the difference that it can be focused on a single sector or cover a number of sectors in a given region.

A business ecosystem is based on the characteristic mechanisms of biological ecosystems, as these networks try to conserve the specificities, tradition and culture of the local and frequently benefit from government incentives (Camarinha-Matos & Afsarmanesh, 2008b). A business ecosystem is similar to the Industry cluster and the industrial district, but it is not bounded by one sector.

Companies that act in social domains as health and personal services, must be able to interact in an efficient way with multiple organizations to achieve personalized offers without losing competitiveness and quality in their services (Baldissera et al., 2017).

Considering the reality of the world in which we live, services that attend the needs and desire of the elderly are of growing demand. However, since everyone is different, it is rare that one service can fulfil every elderly need. In fact, many health-care providers only have companion services, others have consulting services for helping to manage the elderly finances and others promise to help creating a healthier lifestyle (Too Young To Retire, 2003; AARP, n.d; Silversurfers, 2019; AASC – 60Plus, 2018), but none of them is capable of adequate themselves to all the customer's care needs, requirements and priorities, so it is appropriate to consider the need for service composition and a Collaborative Network may be the answer that is sought. The aim of this work, following the work of Baldissera et al. (2017), is to develop an algorithm named SCoPE that will be used in a Business Ecosystem, namely an Elderly Care Ecosystem (ECE), to facilitate the search for the elderly people for the services they need to preserve their quality of life. It will organize the information gathered regarding customers, care needs, services and service providers and will afterwards try to provide the closest match possible between customers and their needs and the service providers and the services they provide.

3

Logical Architecture

3.1 Functional model

In order to achieve the most adequate answer to a customer need, focus will have to be put upon customer, care need, service and service provider. For that, the implementation of the ecosystem was grounded in the ecosystem base model proposer by Baldissera et al. (2017), presented at Figure 3.1.

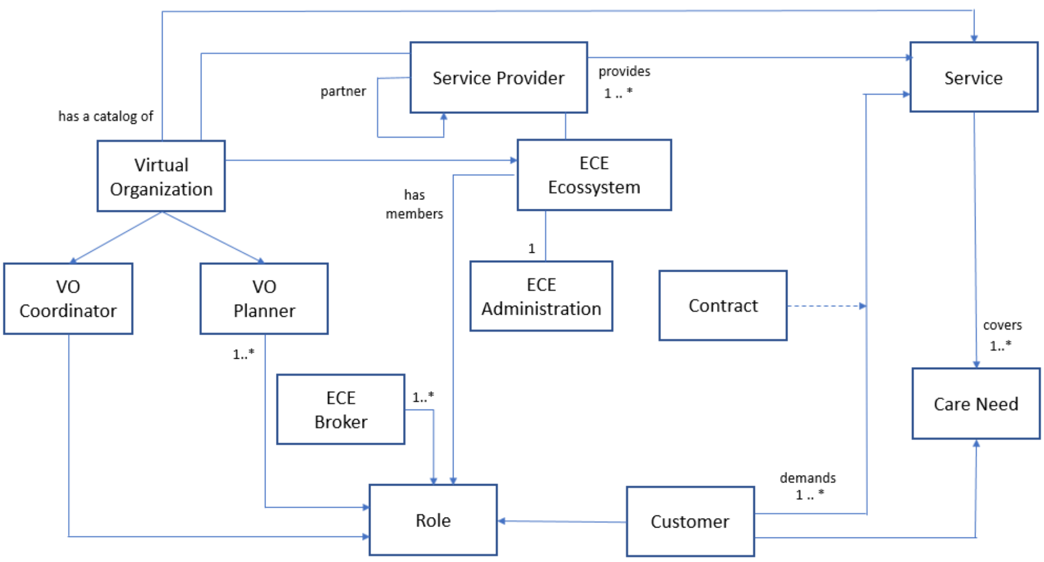


Figure 3. 1 - Elderly Care Ecosystem Base Model (Baldissera et al., 2017)

The ECE will have a designated manager who will be responsible for gathering the information from the customers and service providers. The manager will also be responsible to fulfil the information regarding the available services and the care needs that will be possible to be addressed. Finally, it will also be the manager's responsibility to execute the ECE's algorithm, based on the customer's request, in order to provide different answers to fulfil the needs. This information is on the ECE's schematic tree on Figure 3.2 and on the UML use case on Figure 3.3.

Figure 3. 2 - ECE's schematic tree

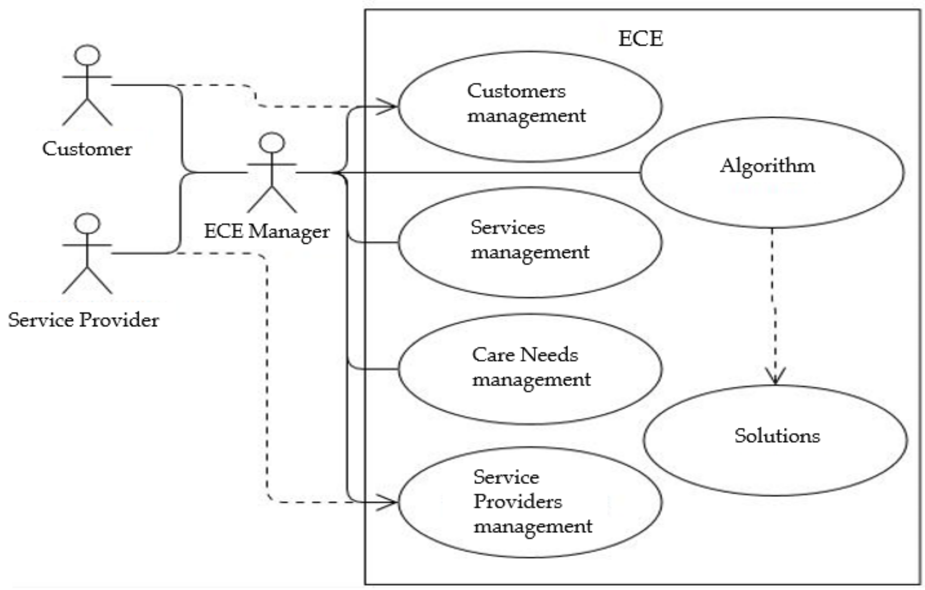


Figure 3. 3 - ECE's UML use case

The ECE manager oversees gathering all the different information as it is shown at the ECE's functionality diagram on Figure 3.4.

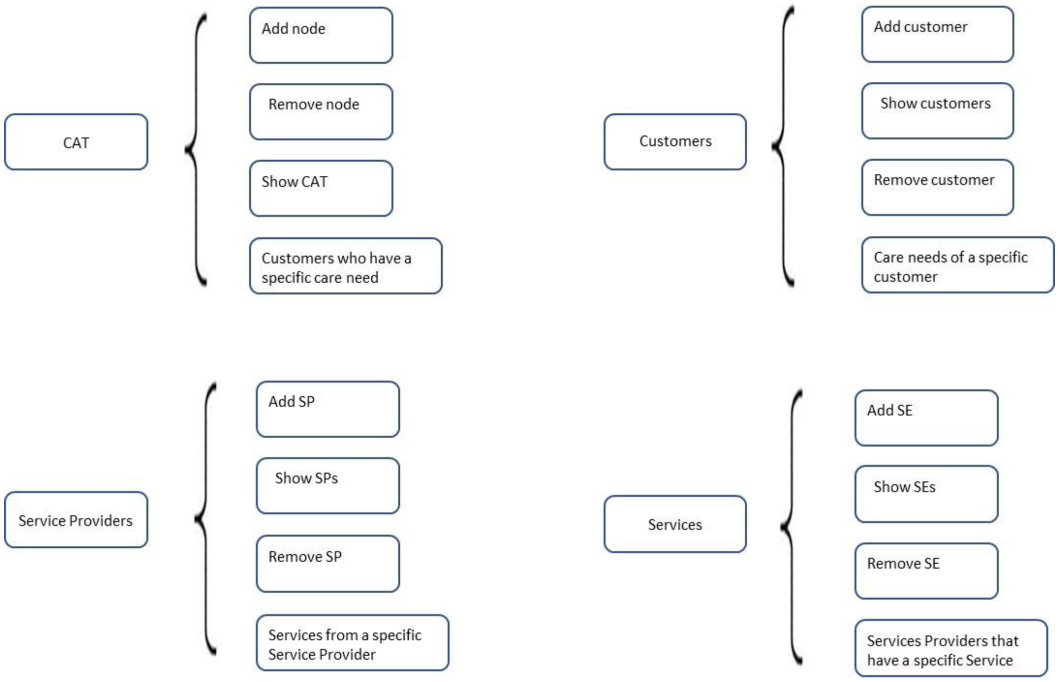


Figure 3. 4 - ECE's functionality diagram

It will be possible for the manager to add, remove and to show the data of a specific customer and related care needs. Regarding the care needs, they will be sorted according to their respective taxonomy (CAT), whether they represent a health need or a need to stay active for instance. The manager will be able to add a new care need as they are deemed necessary, remove them, show them and also to show what care needs are associated to specific customers. Regarding the service providers, the ECE manager will be able to add them, show their information, remove them and to reveal what services are attended by a specific service provider. Finally, as far as the services are concerned, the ECE manager will be able to add new ones, show them, remove them, and to find what service providers have a particular service.

The gathering of information only stands for half of the work that the ECE manager is responsible for. Not only that, but in a further step, the manager will also be responsible for executing the algorithm when the customer asks for it and to provide him/her with the solution for its characteristics.

The ECE working properly will depend in a first glimpse at the proper definition of the senior in need of using the services. In order to achieve that, the customer profile's elements were defined (Baldissera et al., 2017). Ideally, the more information can be gathered as exemplified in Table 3.1, the better are the chances of providing an appropriate answer for the need of the senior citizen (Baldissera et al., 2017). It is also very important that the information related to every customer is updated since if, for example, a customer has a new disease or a new requirement, then that information must be reflected on the ECE in order to assure that, when executing the algorithm, the solution proposed is the ideal one.

Table 3. 1 – Customer profile's elements (Baldissera et al., 2017. Adapted)

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 localization information (e.g. home address, children´s address, everyday local address, etc.).
Life Style	Indicating customer´s individual life style (e.g., how are diary routines, customer´s likes, and dislikes, cultural aspects, spiritual aspects, etc.). The life style identification contributes to enriching the profile and assist 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 frequency (e.g. sports, travels, walks, etc.).
Culture	Describing customer´s cultural activities frequency (e.g. favorite movies, theatre, kind of museums, preferred games, etc.).
Technology	Representing how the elderly deals with technology in his/her daily life (e.g. if she/he 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	Identification of relevant information about the customer´s environment (e.g. educational and professional activities, family structure, etc.).
Education	Involving education level (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 regular medicines, 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 place, 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).

Care needs can be measurable or simply desires from the elderly. For instance, a care need can be the need of a senior to go to the hospital to have a treatment and cannot go by himself. On the other hand, a care need can be the desire of going to the coffee and meet his/her friends. Even though that is not a life-threatening condition, it can be a care need desired by a senior citizen. This means that a person can have one or more care needs, and that those should be evaluated according to their relative importance, like presented in the schematic on Figure 3.5.

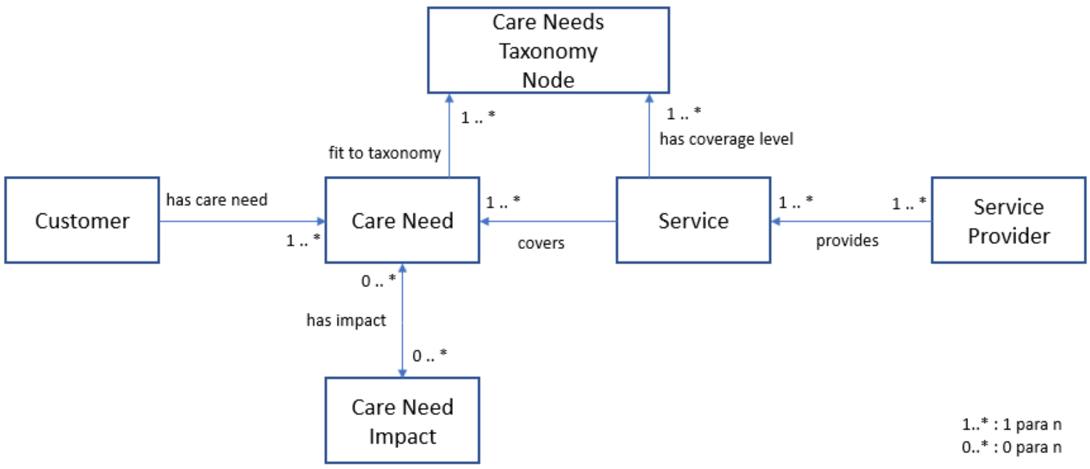


Figure 3. 5 - Care needs' characterization diagram (Baldissera et al., 2017)

Besides, it is considered that the list of available care needs is pre-defined, and the ones considered for this work are presented in Figure 3.6

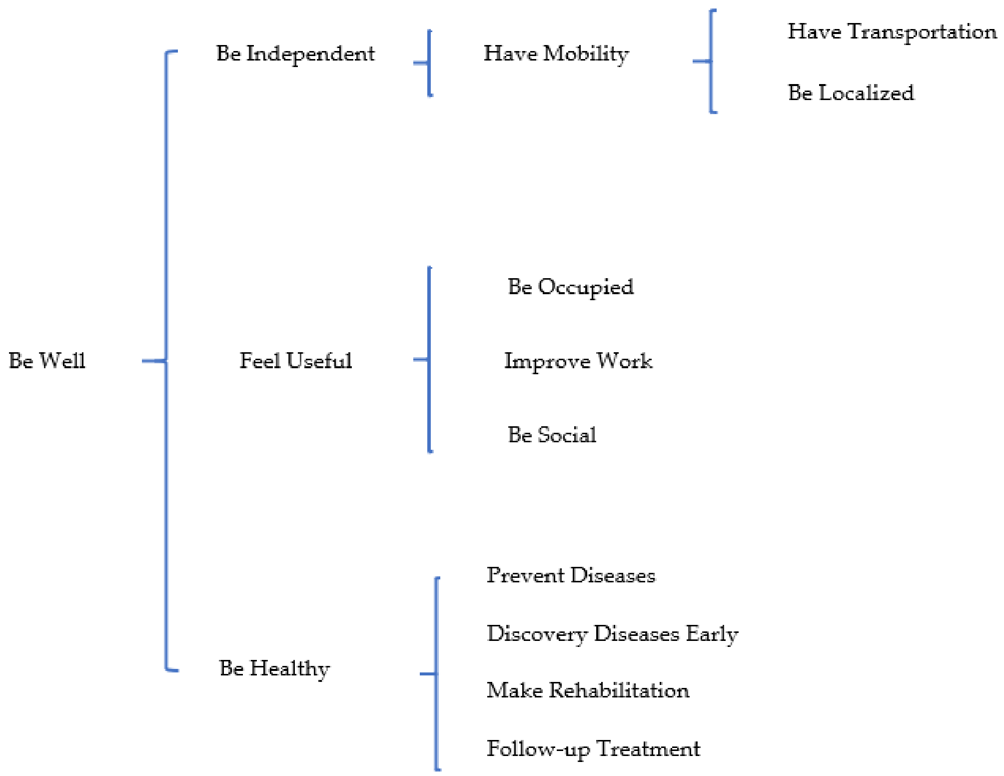


Figure 3. 6 - Care need Taxonomy (CAT) (Baldissera et al., 2017. Adapted)

Each service that exists in the ECE shall attend one or more care needs and for that, the service on itself must follow a characterization scheme similar to the one on Table 3.2.

Table 3. 2 – Service Description (Baldissera et al., 2017, Adapted)

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).
Geographic Area	Representing localization of service coverage. A service might have one or more geographical coverage area (e.g. Latitude: 38.7071, Longitude: -9.13549, 38 ° 42'26 "North, 9° 8'8" West, about Lisbon).
Business Process	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 business process, corresponding to human or software services (e.g. a nurse applies an injection, device sends a reminder, etc.).
Trigger Event	The action that triggers a service request (e.g. identify current location of senior, verify suitable professionals for the task, etc.).
Service Catalogue	Representing a repository of services available on ECE. Services are kept in a catalogue based on four life settings (described earlier) available for consultation when required.
Atomic Service	Indicating a service that has a single business process.
Integrated Service	Indicating a kind of business service which consists of a combination of several other services that turns into a new service.
Service Integrator	Describing an entity that performs service integration. One service may depend on another service, or complement it, stimulating services integration.
Application Constraints	Indicating a situation in which the service cannot be executed, indicating restrictions (e.g. a service that is not suitable for those with visual impairment, for seniors over 90 years old, etc.).
Application Suggestion	Indicating a suggestion of service that can strengthen preferences of customer (e.g. suggestion *friendship* indicating that the service is appropriated for strengthen friendship ties and its relations, suggestion *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 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.
ICT Resource	Describing information and communication technological resources (e.g. Wi-Fi internet, data analysis tool, etc.).
Domain-Specific Device	Describing devices used on a specific domain (e.g. a bracelet, a sensor, etc.).
Human Resource	Describing human resources (e.g. a nurse, a friend, a driver, etc.).
Report Resource	Describing specific data necessary on time (e.g. localization where the service will be delivered, information about senior ´s humor to suggest activities, etc.).

Service providers are also a very important part of the ECE, since they provide care and assistance services to answer to care needs (Baldissera et al., 2017). In a collaborative environment, service providers can join with others to provide integrated services and improved delivery of personalized services.

The service providers characterization diagram used, was the one proposed by Baldissera et al. (2017) and is shown in Figure 3.7.

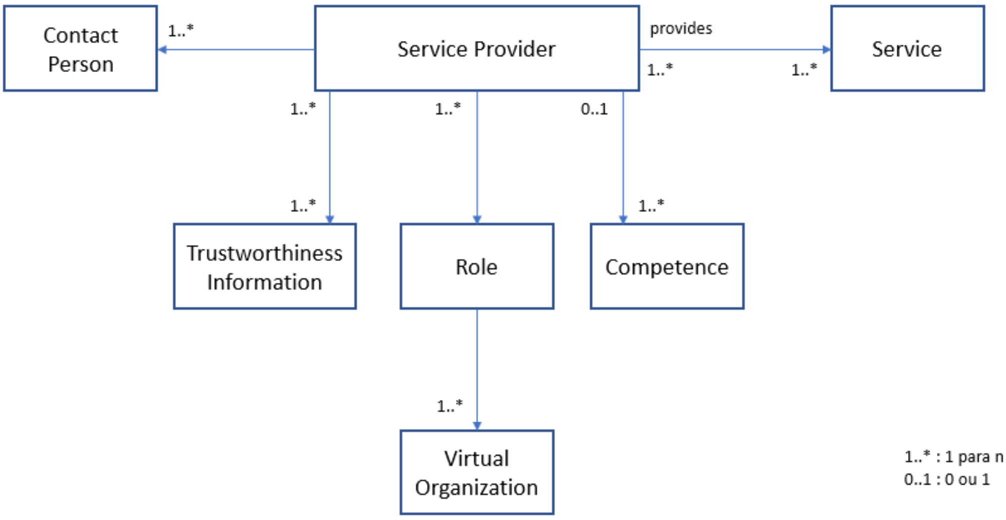


Figure 3. 7 - Provider Characterization Diagram (Baldissera et al., 2017)

The service composition and personalization, named SCoPE, will be accomplished in a four-step method that is illustrated in Figure 3.8.

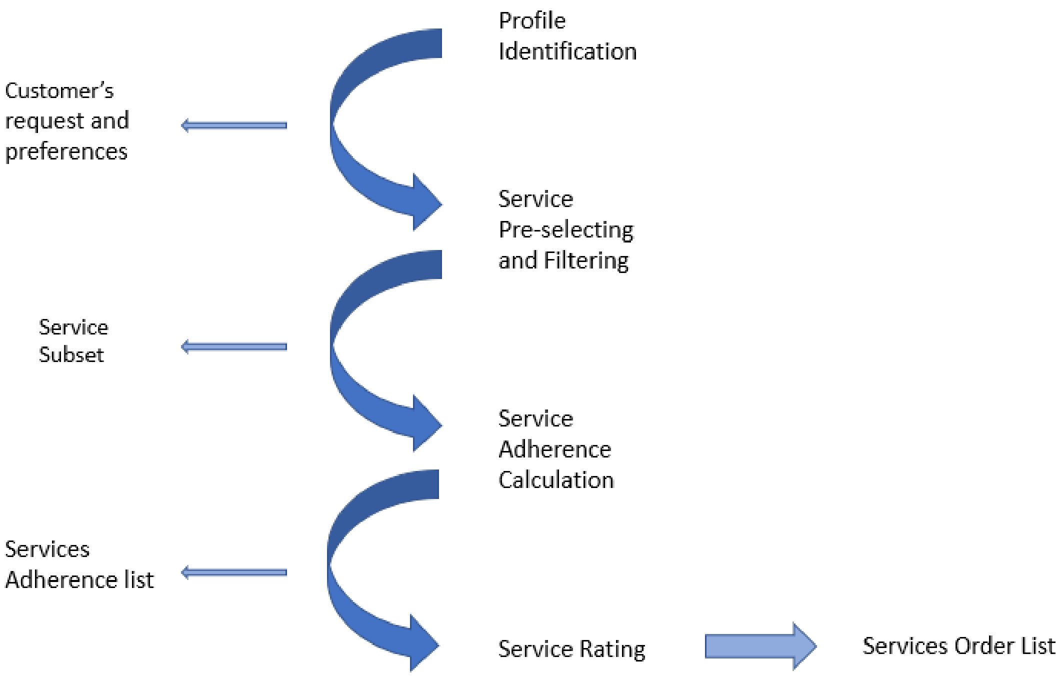


Figure 3. 8 - Service Composition and Personalization Environment (SCoPE) (Baldissera & Camarinha-Matos, 2016. Adapted)

In the first step, the profile identification is essentially a preliminary step where the identification and demands of the elderly are gathered. In the service pre-selection and filtering, from all the services that are available, will be selected those that cover the identified needs. The appropriate restrictions must be applied so that, for example, a service provider that is 300 km away from the customer will not be selected, even though it is capable of performing the desired service.

The third step will be the service adherence calculation which represents a compatibility index between the service, customer's profile and customer's care needs (Baldissera & Camarinha-Matos, 2016). A larger score in the service adherence will represent a better service personalization for the customer. The final step is the service rating where are included not only the service adherence, as the main contributor, but also financial constraints and management strategies.

When all the information has been gathered in the ECE, the manager will be able to, after a customer's request, run the ECE's algorithm in order to provide multiple solutions to address the customer needs. For that, the manager will have to identify which customer he wants to work on. Then, he will have to choose one of two options – New Request or the Algorithm itself. The first option will be chosen in one of two scenarios – either the customer is new in the ecosystem and doesn't have a request yet, or he already has one, but he wants to change it. The second one will run the SCoPE. This schematic tree is show on Figure 3.9. Afterwards it will be up to the customer to choose the preferred solution.

Figure 3. 9 - ECE's Algorithm schematic tree

The ECE's algorithm will start by making an initial selection in all the possible service providers, keeping only the ones that answer the customer's care needs and requirements. Afterwards, for each case, the algorithm will calculate the closeness of each possible solution when compared to the customer's information. Then in the algorithm the G coefficient, which is essentially the average of the obtained values of closeness's, will be calculated. Almost in the end, the partial adherences will be calculated, by combining the value of each G coefficient with the relevance of a requirement for the customer and the associated coverage level from the service. Finally, it will be calculated the average value for the partial adherences, which will result in the Global adherence (Figure 3.10).

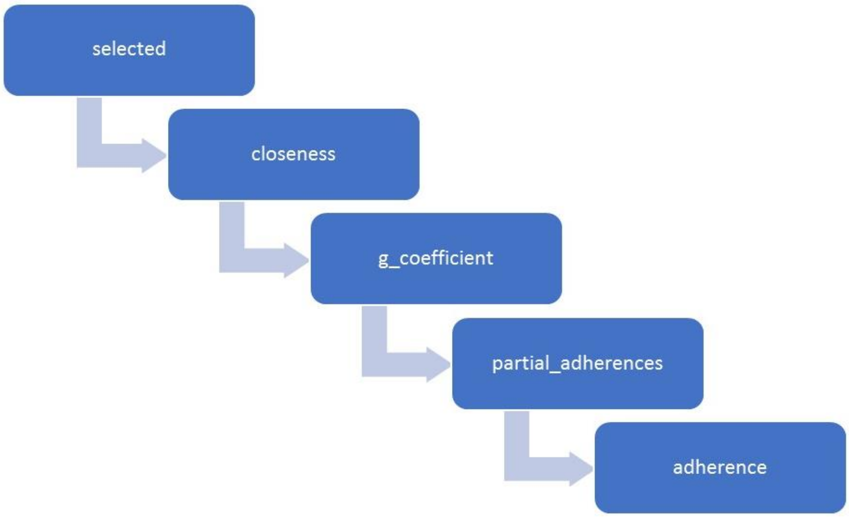


Figure 3. 10 - Algorithm's process

So, to summarize, the usage of the ECE can be seen in the sequence diagram at Figure 3.11.

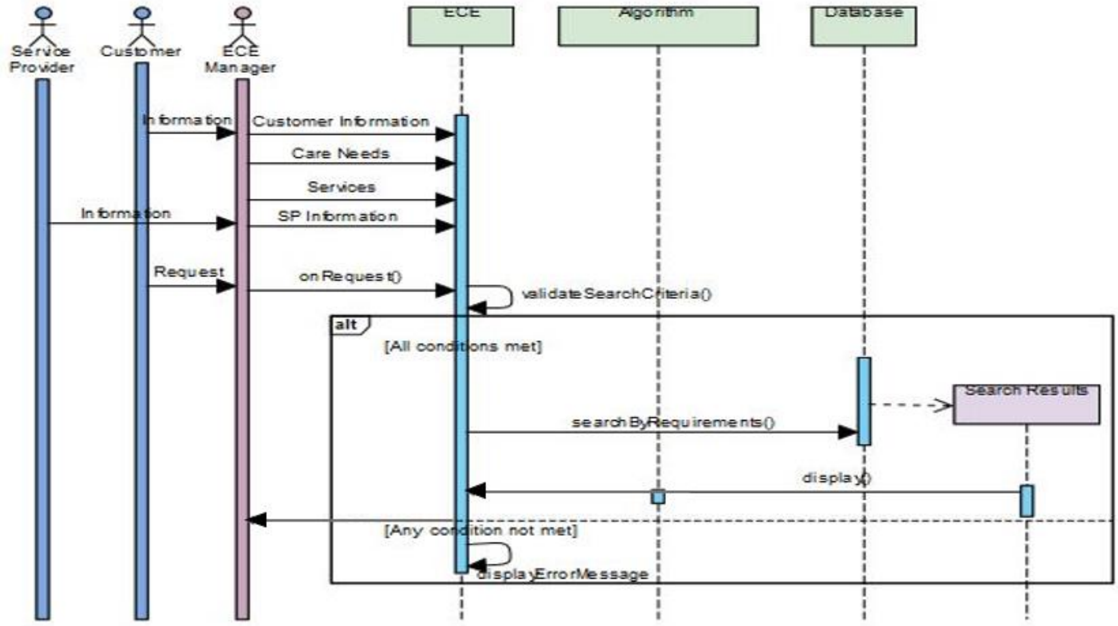


Figure 3. 11 - ECE's UML sequence diagram

Here it can be seen how the ECE manager is responsible for providing the information for the ECE, regarding the Customers and Service Providers (which are given by them) and Services and Care Needs. Afterwards, when the customer requests it, the Manager will run the algorithm to find the most suitable answers for his needs. In a first step, the search criteria will be validated, which means that if no service answers the customer's care needs, or if the customer's hard constraints are not met by any of the services that cover the customer's care needs, or if the services' limitations make the them unavailable for the customer, then no results will be found. If the search criteria are validated, then the algorithm will be executed selecting the different services and service providers pairs that will meet the customer's needs.

Even though the explanation of the ECE can be done in a quite simplistic way, the truth is that behind it are some more complex relations, as illustrated in Figure 3.12.

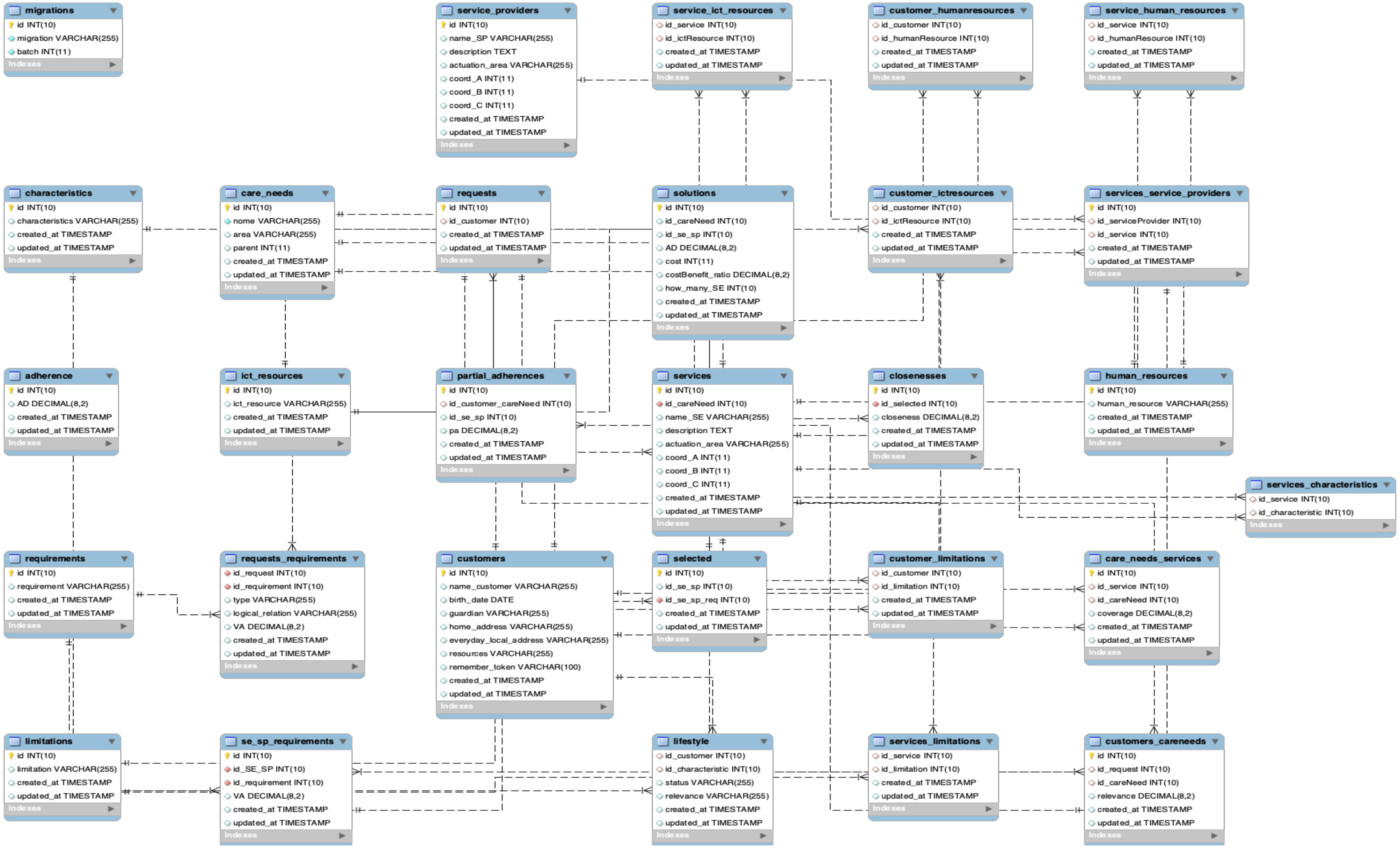


Figure 3. 12 - ECE's Entity Relationship Diagram

3.2 Functionalities of the ECE

As mentioned before, considering the data gathered from the elderly and the service providers, the ECE will, per customer request, provide the different answers that meet the customers' needs.

The first answer will consider the Adherence Maximization meaning that from all the possible answers to meet the elderly needs, they will be ranked respecting to how close are the services to the elderly demands. The second answer favours the cost-benefit ratio, which means that it will rank the possible answers based on their price.

The final solution provided to the customer will take into consideration the number of services maximization which means it will evaluate how many service providers are necessary to answer the customer's request.

None of the provided answers is intended to be a definitive answer to a customer's request. The goal of the ECE is to provide different possibilities so that the elderly can make an educated choice regarding its needs.

The ECE functionalities are presented in Figure 3.13.

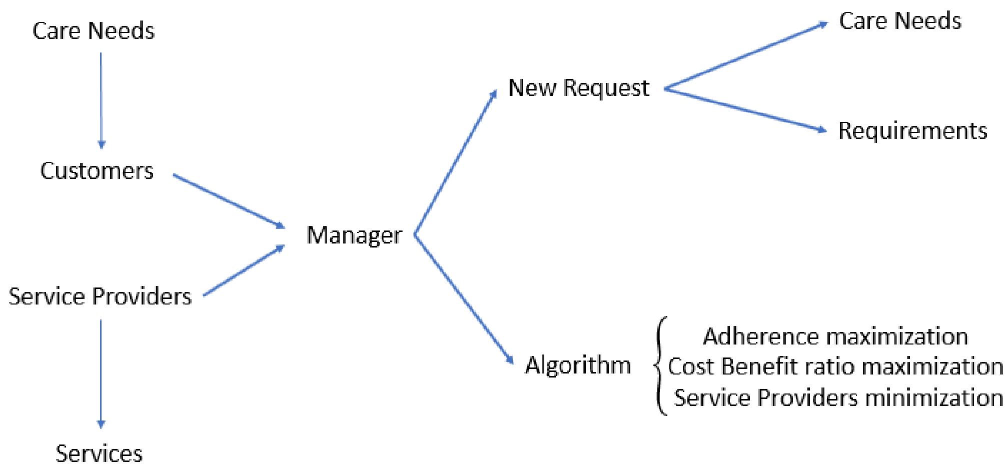


Figure 3. 13 - ECE functionalities

As it was mentioned, the ecosystem is compound by customers, which are the elderly, their specific care needs and requests, and by service providers who will afford services in order to try to give the most adequate response to the elderly's demands and it's handled by a manager. The customers and service providers will provide information regardless their profile, as detailed as possible. The manager, in turn, will pass all this information to the ecosystem.

At the request of a customer, the manager will run the algorithm and he has two options. The first one is to create a New Request, the second one is to run the algorithm itself. If the chosen option is the New Request one, the customer will be asked to inform which care needs he has and what are his requirements (the maximum price he’s willing to pay, how much time he can wait for the delivery, how good his technological skills are, etc.). If the chosen option is the other one, the algorithm will be run and it’ll give the possible answers according three criteria: Adherence maximization, Cost Benefit ratio maximization and Service Providers minimization.

4

Implementation Structure

4.1 Implementation Technologies

There are several collaborative platforms available on the market, so it was necessary to spend some time using and comparing each one. The work started with some theoretical research, in order to understand which one would better meet the requirements, but it was find inconclusive, because all of them had several similar characteristics, and if one was better in a specific feature, the other one was better in another. So a more practical comparison was needed, and that took a long a time. Platforms like Drupal, WordPress or Grails were tested, but did not produce the expected results. Eventually, Liferay was the chosen one, due to its solid technology foundation, fully featured, fully customizable, easy to use, with a solid record of success, and a forward-looking, bright vision which support the site's future (Liferay homepage, 2017).

Liferay is a collaborative platform that allows building a website quickly and in an open source ("Liferay - Home page," 2017). Other platforms were considered as it is demonstrated in Table 4.1.

Table 4. 1 - Comparison between different support collaborative platforms

Summary	Document Management	User Management	Tasks and Project Management	Compatibility and Adaptability	Security
Grails	* * *	* *	* *	* * *	* *
Liferay	* * *	* * *	*	* * *	* * *
Drupal	* *	* * *	* * *	* *	* * *
OutSystems	*	* *	* * *	* * *	* * *

Since in average Liferay got the better results, it was the chosen platform to work with.

However, several problems were found because Liferay works with plugins that are created by different developers, which would make it a very complicated task to make them communicate with each other. Not only that, but also almost all those plugins worked with its own database. Also, because Liferay is essentially a Web Content Management (WCM) and what was needed was, in fact, something that would enable the development of web applications. With that in mind, Laravel was the chosen tool for the development of the ECE.

Laravel is a web application framework with expressive, elegant syntax. Laravel endeavours to take the pain out of development by expedite routine tasks used in the majority of web projects, such as authentication, routing, sessions, and caching. Laravel aims to make the development process a pleasant one for the developer without sacrificing application functionality. Laravel is accessible, yet powerful, granting powerful tools essential for large, robust applications. A superb inversion of control container, expressive migration system, and tightly integrated unit testing support give the developer the tools he needs to build any application (Laravel, 2013).

Furthermore, the chosen local development environment was Laragon and the database server was MariaDB.

4.2 MVC Model

MVC stands for Model, View and Controller and applications that use this architecture are detached into these three components.

Originally, MVC's purpose was to give the impression of a direct link from the end user brain to the computer (Reenskaug & Coplien, 2009). However, its definition evolved into nowadays where a Model-View-Controller (or MVC) is a specific methodology for coding that is commonly used for developing user interfaces, organizing the code and dividing an application into three interconnected parts (codeacademy.com). This is performed to create different internal representations of information from the ways information is presented to the user. The MVC design pattern divides these major components allowing for efficient code reuse and parallel development. Traditionally used for Graphical User Interfaces, this architecture has become popular for designing web applications. Popular programming languages like Java, C# and PHP have MVC frameworks that are used in web application development straight out of the box.

The three components of an MVC model are so, Model, View and Controller. Model is the central component of the pattern and typically represents the physical world (codeacademy.com). It is the application's dynamic data structure, independent of the interface and it directly manages the data, logic and rules of the application. View is everything that is responsible for interacting with the user (codeacademy.com). It stands for any representation of the information such as a chart, diagram or table. The Controller, in the end, accepts inputs and converts it into commands for the model or view, which means that it is the bridge that connects model and the view (codeacademy.com).

MVC intends to be used in situations for simultaneous development of the applications and code reuse and it is available for using in different platforms such as Java, Phyton and PHP.

Laravel as a free, open-source PHP web framework is 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, utilities that aid in application deployment and maintenance, and its orientation toward syntactic sugar (Edutech expo, 2019).

4.3 Platform Implementation

As it was previously mentioned, the fundamentals of an ECE are the customers that will use it and their care needs, the services that are available that will try to fulfil the customer's care needs and the service providers who provides the services. So, in this ECE all the four possibilities are accounted for.

The ECE system will be managed by an administrator that, for instance to add a customer to the ECE, in the home page (Figure 4.1), the administrator will have a field to select to add a new customer (Figure 4.2).

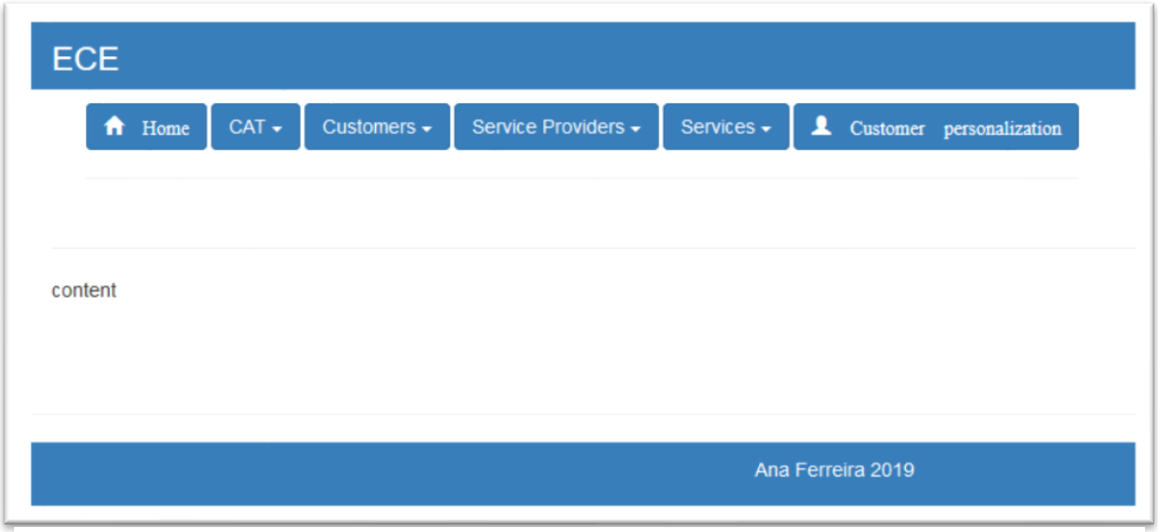


Figure 4. 1 – ECE's homepage

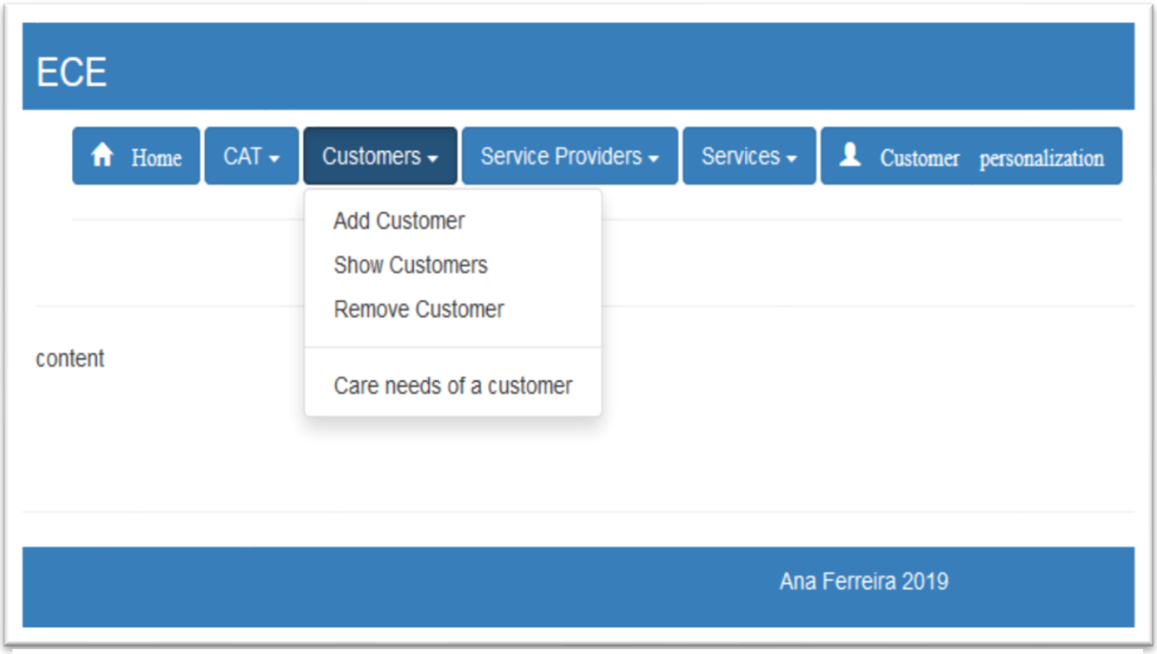
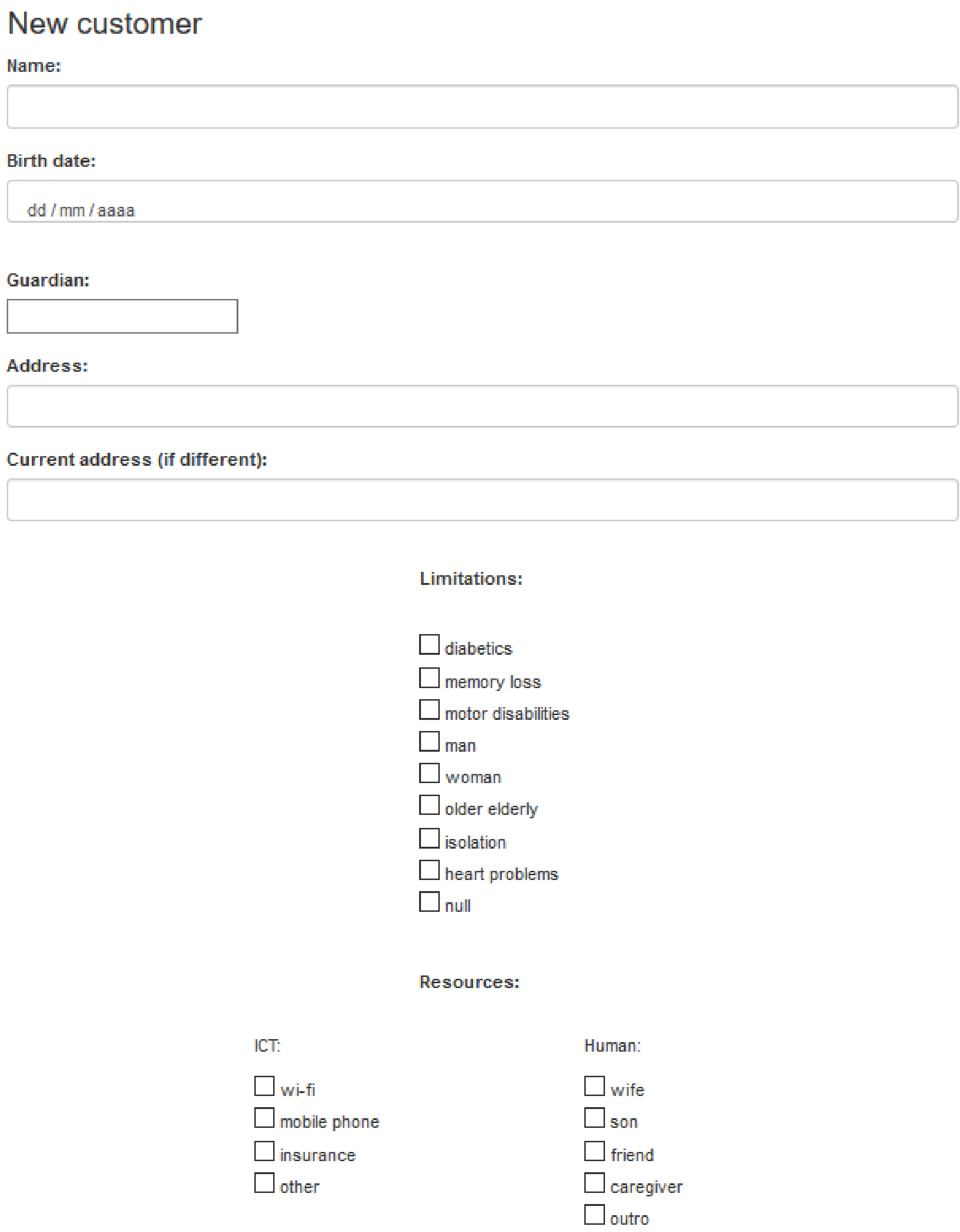


Figure 4. 2 - Add Customer

Afterwards, the manager will follow for a new window in which he will provide all the customer's relevant personal information that has previously been discussed, like name, address, its contact person and its needs (Figure 4.3).



New customer

Name:

Birth date:

dd / mm / aaaa

Guardian:

Address:

Current address (if different):

Limitations:

- diabetics
- memory loss
- motor disabilities
- man
- woman
- older elderly
- isolation
- heart problems
- null

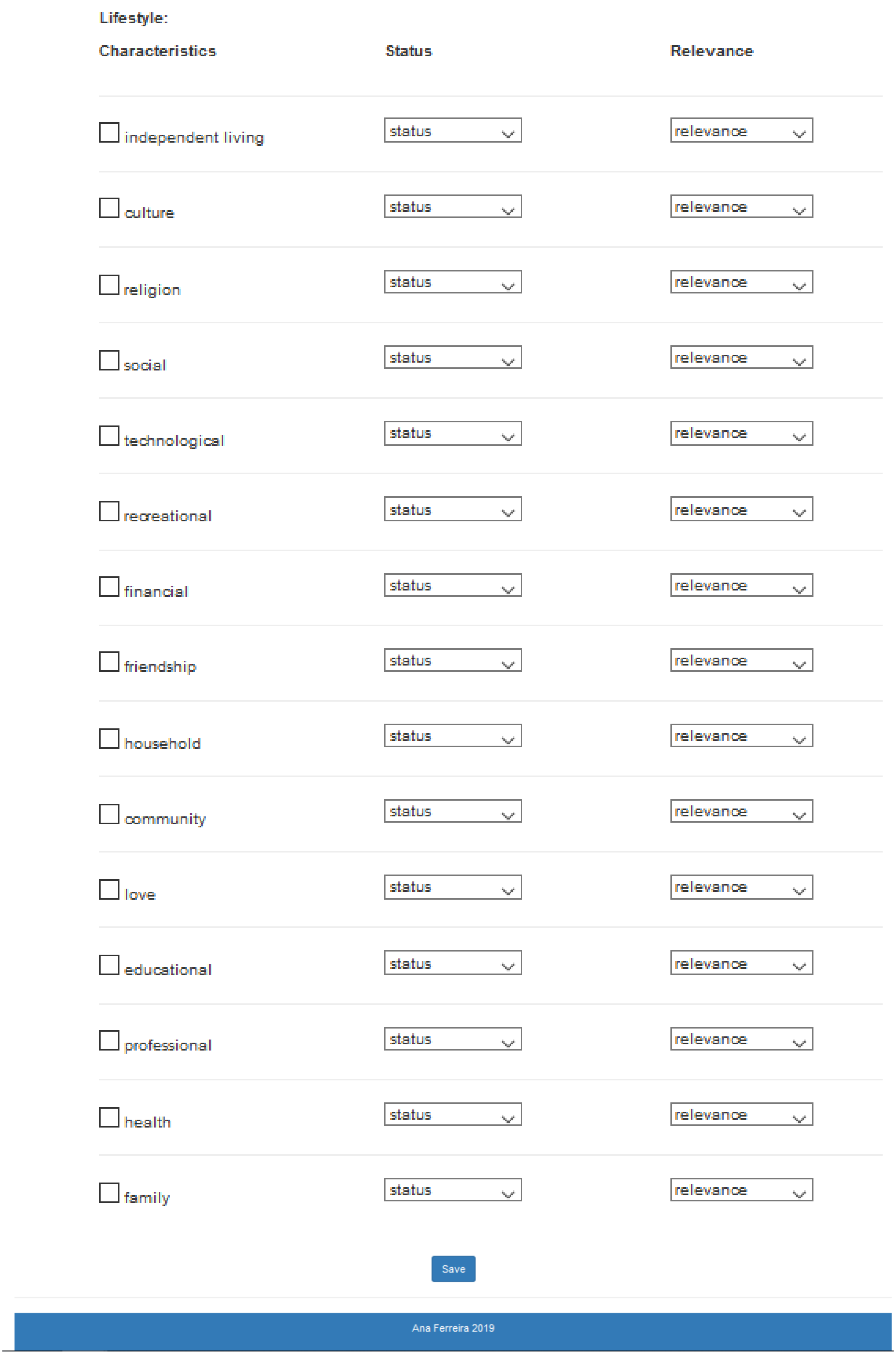
Resources:

ICT:

- wi-fi
- mobile phone
- insurance
- other

Human:

- wife
- son
- friend
- caregiver
- outro


Lifestyle:

Characteristics	Status	Relevance
independent living	status	relevance
culture	status	relevance
religion	status	relevance
social	status	relevance
technological	status	relevance
recreational	status	relevance
financial	status	relevance
friendship	status	relevance
household	status	relevance
community	status	relevance
love	status	relevance
educational	status	relevance
professional	status	relevance
health	status	relevance
family	status	relevance

Save

Ana Ferreira 2019

Figure 4. 3 - New customer form

In Figure 4.4 it is illustrated how a new service can be created and added to the ECE. In the home page of the ECE, it is possible for the ECE administrator to select a field to add a new service.

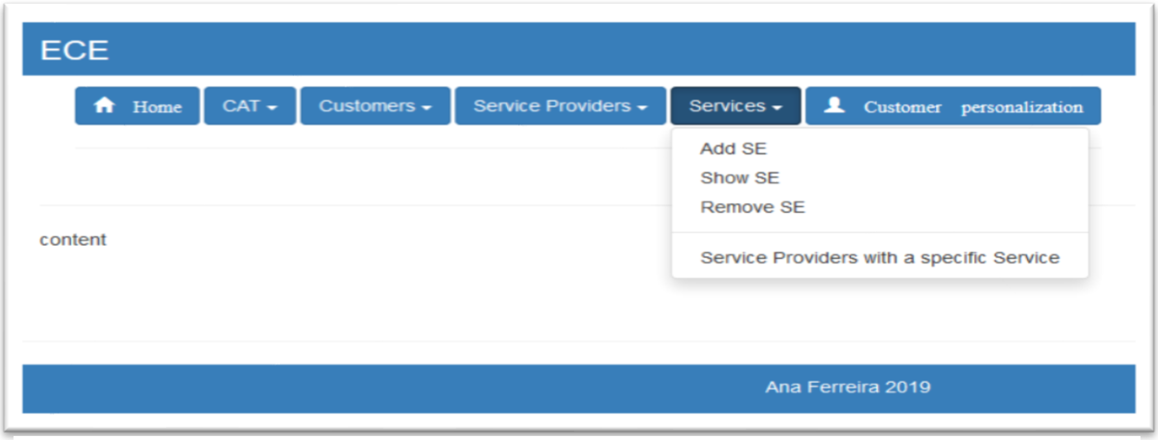


Figure 4. 4 - New service

Similarly, to the customer, some information will have to be provided (Figure 4.5).

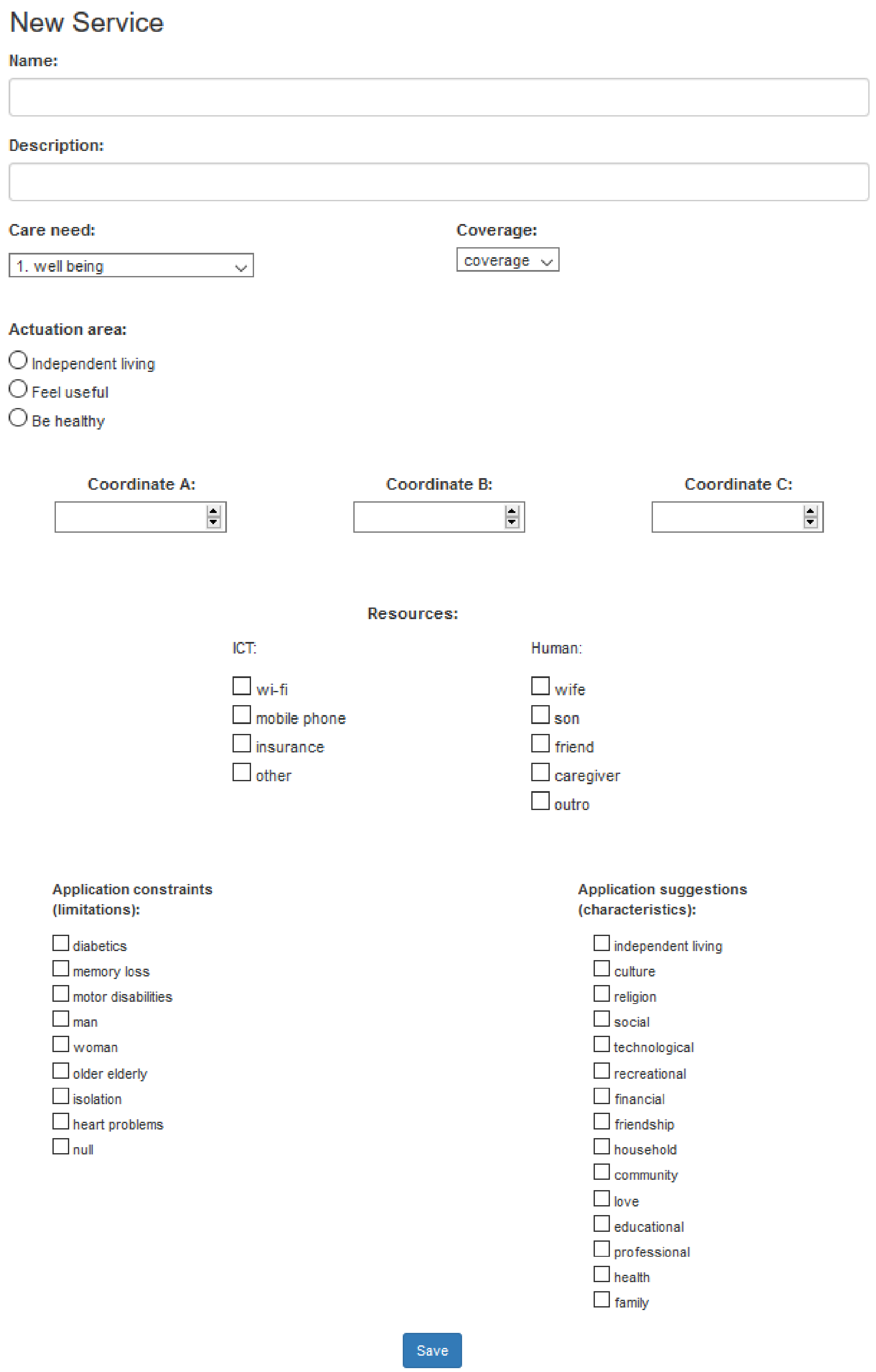

New Service
Name:
Description:
Care need:
1. well being
Coverage:
coverage
Actuation area:
Independent living
Feel useful
Be healthy
Coordinate A:
Coordinate B:
Coordinate C:
Resources:
ICT:
wi-fi
mobile phone
insurance
other
Human:
wife
son
friend
caregiver
outro
Application constraints (limitations):
diabetics
memory loss
motor disabilities
man
woman
older elderly
isolation
heart problems
null
Application suggestions (characteristics):
independent living
culture
religion
social
technological
recreational
financial
friendship
household
community
love
educational
professional
health
family
Save

Figure 4. 5 - New service form

Finally, through Figure 4.6, it is demonstrated how a service provider is added to the ECE. Like before, there is the possibility to select a field to add a new service provider.

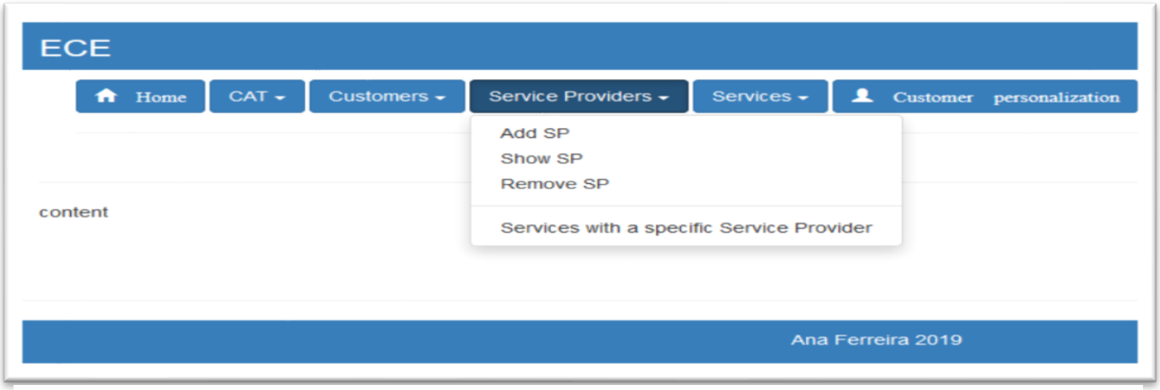


Figure 4. 6 - New service provider

And again, similar to what happened when adding a new customer, the new service provider will have to provide numerous information, namely the services it provides (considering that the services are already registered), and some of its characteristics (Figure 4.7).

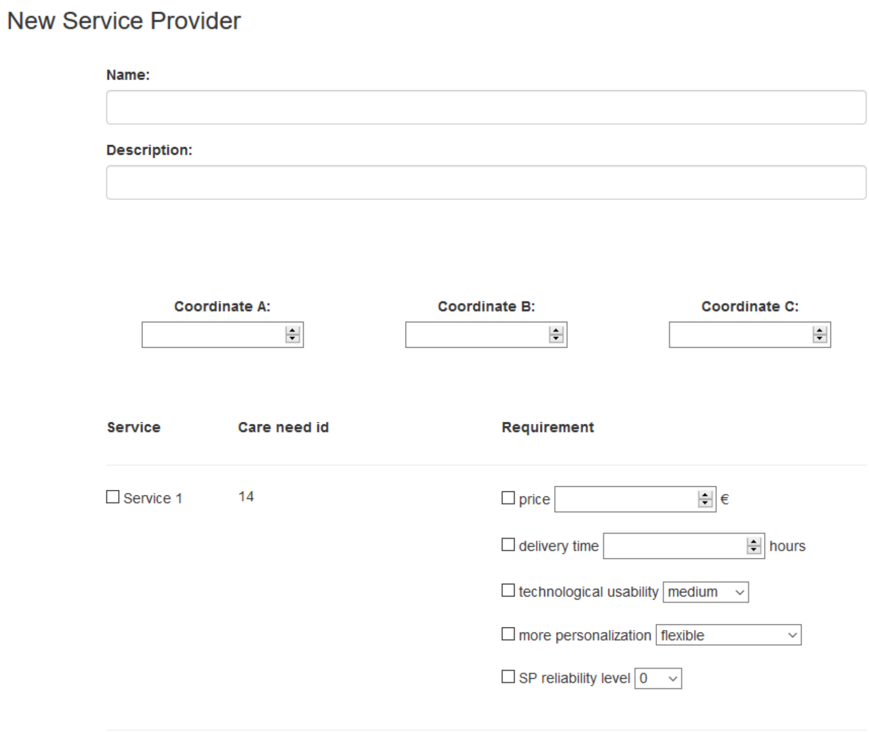


Figure 4. 7 - New service provider form

Even though the ECE is managed and the information filled by the administrator, in each of the four different perspectives, the reality is that it is meant to provide answers for its customers.

Finally, the platform will have the option to create a PDF with all the information related to the algorithm's suggestions, that can be exported. An image of the PDF is presented in Figure 4.8.

Solutions for Adherence Maximization

care need	service name	service provider name	AD	cost	cost benefit ratio	number of services
recreational activities	Aging with sport	Here4U	0.65	80	0.81	3
transportation	OnWheels	Here4U	0.47	160	0.29	3
transportation	OnWheels	The magic van	0.47	90	0.52	1
recreational activities	Mens sana corpore sano	Here4U	0.42	60	0.70	3

Solutions for cost benefit ratio

care need	service name	service provider name	AD	cost	cost benefit ratio	number of services
recreational activities	Aging with sport	Here4U	0.65	80	0.81	3
recreational activities	Mens sana corpore sano	Here4U	0.42	60	0.70	3
transportation	OnWheels	The magic van	0.47	90	0.52	1
transportation	OnWheels	Here4U	0.47	160	0.29	3

Solutions for number of services maximization

care need	service name	service provider name	AD	cost	cost benefit ratio	number of services
transportation	OnWheels	Here4U	0.47	160	0.29	3
recreational activities	Aging with sport	Here4U	0.65	80	0.81	3
recreational activities	Mens sana corpore sano	Here4U	0.42	60	0.70	3
transportation	OnWheels	The magic van	0.47	90	0.52	1

Figure 4. 8 - PDF created by the platform

4.4 Algorithm Implementation

The first step of the algorithm is intended to make a first approach, selecting only the pairs service-service provider that provide a valid answer to the customer's needs and requirements.

The second step of the algorithm is the Adherence calculation. This step is meant to determine a compatibility index relating the customer profile, requirements and priorities to the provider's characteristics and care services features (Baldissera & Camarinha-Matos, 2018a). The concept of adherence intends to provide a combined view of how good the match between the service and the need is. The larger the adherence is, the more appropriate the service is for a given customer's profile (and thus the smaller is the probability to obtain a mismatch).

The adherence is calculated for each pair of service and service provider that will be a possible solution for the customer's care need and it is calculated by estimating the three coefficients that are shown in Figure 4.9: Closeness (CL), Partial Adherence (PA) and Adherence (AD).

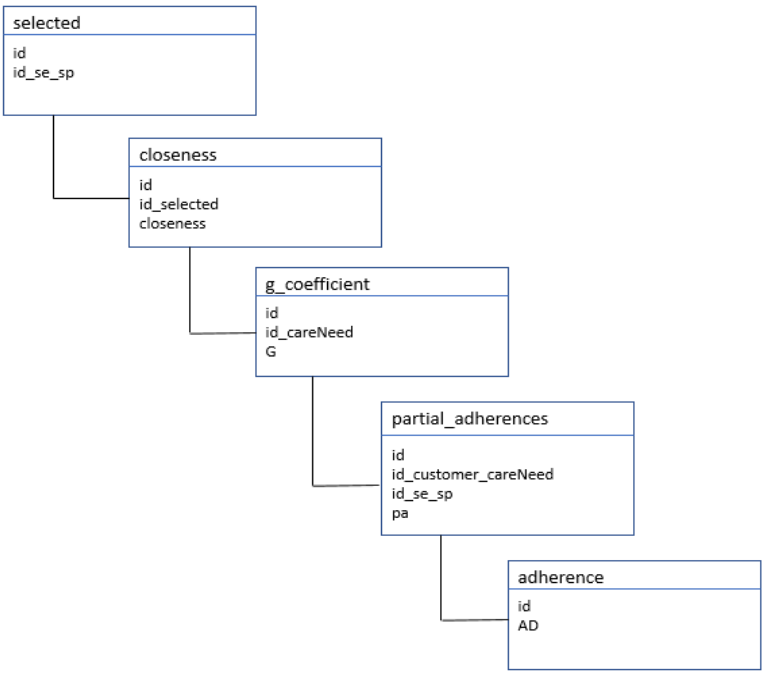


Figure 4. 9 – Fragment of Algorithm's Entity Relationship Diagram

This diagram is a fragment of the one presented in Figure 3.12, and represents the part of the algorithm per se.

Since it is aimed to the best possible service personalization and adaptability for each customer, 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 is based on each customer's requirement. CL considers how far apart are customer's requirements and the related features of the pair {service, service provider}. The larger the distance is, the smaller the CL is. As each customer has different needs/requirements, the same service and provider fragment can have a different closeness to each customer.

4.4.1 CL Calculation

In what concerns to this work, CL calculation considers three different possible situations:

1) when the customer's requirements and the features of the pair service, service provider are quantitatively expressed (crisp), for example, the maximum price he is willing to pay
2) when the customer's requirement and the features of the pair {service, service provider} are qualitatively expressed (fuzzy), like the customer's level of technological knowledge
3) when the customer's requirement relates to service adaptability, for instance, if the customer requests a car with a specific colour for delivering a service, the request has a very high demand level and therefore requires a great flexibility from the service provider

$$CL = \begin{cases} cl_{crisp} & , if\ requirements\ are\ expressed\ in\ crisp\ value \\ cl_{fuzzy} & , if\ requirements\ are\ expressed\ in\ fuzzy\ scale \\ cl_{flex} & , if\ requirements\ are\ presuppose\ flexibility \end{cases}$$

The initial classification of the {service, service provider} pair features can be given by the ECE stakeholders, like service provider members or by professionals in elderly care. Some values might not be available yet (if the service has not been rated yet) or not necessary for the customer (if he has no constraints) (Baldissera & Camarinha-Matos, 2018a).

It is considered that all {service, service provider} pairs that can offer at least the same features' values when compared with customer's requests have the greatest closeness value, which is 1, corresponding to the optimal solution (Baldissera & Camarinha-Matos, 2018a). For the other cases, the closeness is calculated based on the distance of the customer's requirements to what the service provider offers. Following the possible situations, the specific way of calculating the closenesses will be shown:

<u>CL calculation for a crisp value</u>:

$$cl_{crisp} = \frac{customer's\ requirement}{\{service, provider\}\ fragment\ feature}$$

<u>CL calculation for a fuzzy value</u>:

$$cl_{fuzzy} = 1 - d(£_1, £_2)$$

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

Where the values of a_i and b_i depends on the linguistic term (Table 4.2):

Table 4. 2 - Fuzzy linguistic terms for CL

Linguistic Term	**Fuzzy Number**
Very low	(0.0, 0.0, 0.12, 0.22)
Low	(0.12, 0.22, 0.34, 0.44)
Medium	(0.34, 0.44, 0.56, 0.66)
High	(0.56, 0.66, 0.78, 0.88)
Very high	(0.78, 0.88, 1.0, 1.0)

<u>CL calculation based on service provider flexibility</u>:

Flexibility is the ability to incorporate variations in the execution of the care service within a process definition by customer request. As such, the specific request is represented by parameters characterizing the flexibility level (Baldissera & Camarinha-Matos, 2018a). The flexibility zones are the following (Table 4.3).

Table 4. 3 - Parameters characterizing the flexibility level

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

It's important to note that these calculations use fuzzy logic to maintain coherence with the work already developed in the PhD project, where the ECE and the algorithm are inserted.

At the end, a closeness vector is calculated, where the number of elements match the number of requirements of each selected {SE, SP} fragment, foreach customer's care need.

4.4.2 Adherence Calculation

The second calculated coefficient of the algorithm is the partial adherence. The partial adherence calculation starts with the calculation of G, which is the average of the closenesses of all care needs, for each care need. The G coefficient is given by

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

The calculation of the partial adherence combines what's called the G coefficient with the comparison of the service coverage level (CO) with the customer's care needs relevance (RL). For each care need a different value of partial adherence will be calculated. The CO is attributed when a service is registered in the ECE and it is associated with a care need. The RL is defined by the customer when the care need is requested, meaning that he will define how vital is the care need for him. CO and RL coefficients are expressed in a fuzzy scale. However, they are often checked and adjusted at any time, if necessary.

$$pa_m = \begin{cases} G(cl_m).\,|1 + distance(CO_m, RL_m)| & if\ cov_m \geq rl_m \\ G(cl_m).\,|1 - distance(CO_m, RL_m)| & otherwise \end{cases}$$

At the end, the vector PA is calculated in which the number of elements correspond to the number of customer's care needs, and afterwards the adherence will be calculated as an average of the PA's of each {SE, SP} selected pair.

$$ad = \frac{1}{m}\sum_{x=1}^{m} pa_x$$

4.4.3 Final Results

Finally, the algorithm will have completed its task when it does service composition and ranking. In this final step, the {service, service provider} pairs that have been evaluated and which adherences were calculated will be rated and there will be a suggestion of composition of services based on selected strategies. The solution will be presented in terms of lower cost, in terms of better cost/benefit ratio and in terms of providers minimization.

So, after the algorithm has generated the solution for the customer, a PDF document will be created, as shown in Figure 4.8, and may be sent to the customer so that he will be able to choose the solution that best fits his interest.

5 Validation

The goal of the present work is to provide an answer to the question of how to provide personalized collaborative care services for elderly in an effective and reliable way. The ECE's purpose was achieved by running an algorithm that considers the information provided by the customers and service providers in order to yield different solutions that may fulfil the customers' needs, based on different criteria. In a first approach, each customer may only have an active request in which there can be one or more care needs that belong to one out of three areas: independent living, feel useful and be healthy and a set of requirements, like it was mentioned earlier.

The algorithm can be divided into 2 different subjects, the management part and the matching part. In the management part, the algorithm is responsible for organizing the information related to the customers, their care needs, services and service providers. In the matching part, the algorithm is responsible for providing the most appropriate matches between customer's needs and services available due to the service providers. The matching part is divided into 3 main steps that are: Service Pre-selecting and Filtering, Adherence Calculation and Service composition and ranking. The first step is intended to make a quick clean from the data that exist in the ECE database. As a first approach, the algorithm will search for any service that covers any of the care needs that the customer singled out and will not take the others into account. This process is based on the goals of the taxonomy of care needs and customer's requirements and limitations, because for instance if a customer is diabetic and the service is not suited for diabetic than that match will be eliminated even if other criteria is met. Secondly it will search in the customer's requirements which are the most important for him, the one's he has marked as a hard request and it will eliminate the service that don't meet those demands.

5.1 Scenarios

In order to demonstrate the ecosystem functionality and the algorithm's performance, a scenario with three customers is presented. The first customer's name is José Marques. José Marques' birth date is 09 November 1933 and he lives in Lisbon. He has a daughter who is his guardian.

José has three care needs – Recreational activities, Cognitive stimulation and Diet planning, with relevance 0.75, 0.50 and 0.75, respectively. Besides, he suffers from diabetics and memory loss.

Mr. Marques has a daughter who visits him often and helps in what she can. His lifestyle is present at Table 5.1.

Table 5. 1 - Mr. Marques' lifestyle table

Characteristic	Status	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

Furthermore, he has access to wi-fi at home and possesses a health insurance. Finally, José Marques' requirements are present at table 5.2.

Table 5. 2 - Mr. Marques' requirements table

Requirement	Constraint type	Logical relation	Value
Price	Hard	≤	150.00
Delivery time	Hard	≤	48
Technological usability	Soft	n.d	0.75
More personalization	Soft	n.d	0.50
SP reliability level	Soft	n.d	4.00

The second customer is Teresa Costa who was born on 02 June 1940 in Aveiro, but now she lives in Lisbon.

She has three care needs – Transportation, Recreational activities and Cognitive stimulation – and two limitations – motor disabilities and isolation.

Mrs. Costa's lifestyle is presented at Table 5.3.

Table 5. 3 - Mrs. Costa's lifestyle table

Characteristic	Status	Relevance
Independent living	Not active	Very important
Culture	Active	Important
Religion	Highly active	Not important
Social	Not active	Very important
Technological	Active	Important
Recreational	Highly active	Not important
Financial	Not active	Very important
Friendship	Active	Important

Household	Highly active	Not important
Community	Not active	Very important
Love	Active	Important
Educational	Highly active	Not important
Professional	Not active	Very important
Health	Active	Important
Family	Highly active	Not important

She has wi-fi and mobile phone resources.

Her requirements are presented at Table 5.4.

Table 5. 4 - Mrs. Costa's requirements table

Requirement	Constraint type	Logical relation	Value
Price	Soft	≤	100.00
Delivery time	Soft	≤	24
Technological usability	Hard	n.d.	0.00
More personalization	Soft	n.d.	0.75
SP reliability level	Soft	n.d.	4.50

The last considered customer for the scenario is Mrs. Lurdes Fortunato. Lurdes was born on 25 December 1938 and lives in Lisbon with her son. She has a caregiver, who spends the week days with her.

Mrs. Fortunato has three care needs, which are Transportation, with relevance 0.75, Recreational activities, with relevance 0.50 and Diet planning, with relevance 0.25. She also suffers from heart problems. Mrs. Fortunato lifestyle is shown in Table 5.5.

Table 5. 5 - Mrs. Fortunato's lifestyle table

Characteristic	Status	Relevance
Independent living	Active	Important
Culture	Active	Important
Religion	Not active	Important
Social	Not active	Very important
Technological	Highly active	Important
Recreational	Highly active	Important
Financial	Active	Important
Friendship	Not active	Very important
Household	Highly active	Important
Community	Highly active	Not important
Love	Not active	Not important
Educational	Active	Not important
Professional	Not active	Not important
Health	Active	Very important
Family	Highly active	Very important

Lurdes has a health insurance and has recently bought a mobile phone.

Her requirements are presented at Table 5.6.

Table 5. 6 - Mrs. Fortunato's requirements table

Requirement	Constraint type	Logical relation	Value
Price	Soft	≤	80.00
Delivery time	Soft	≤	96
Technological usability	Soft	n.d	0.50
More personalization	Hard	n.d	1.00
SP reliability level	Soft	n.d	5.00

Along with these three different customers, there are also some Services and Service Providers that are considered in the scenario, each with its own actuation area, care need it attends, description and application limitations (Tables 5.7, 5.8, 5.9, 5.10, 5.11, 5.12, 5.13, 5.14, 5.15, 5.16, 5.17 and 5.18):

Table 5. 7 - Service Aging with sport

Name	**Aging with sport**
Actuation area	Feel useful
Care need	Recreational activities
Description	Our goal is to provide you with a way to stay healthy while ageing.
Limitations	Memory loss

Table 5. 8 - Service OnWheels

Name	**OnWheels**
Actuation area	Independent living
Care need	Transportations
Description	We will get you anywhere.
Limitations	None

Table 5. 9 - Service What's on the agenda?

Name	**What's on the agenda?**
Actuation area	Feel useful
Care need	Recreational activities
Description	We will make it our business for you to be where you have to be at the time you need.
Limitations	None

Table 5. 10 - Service Mens sana corpore sano

Name	Mens sana corpore sano
Actuation area	Feel useful
Care need	Recreational activities
Description	If you are staying active, you have endless possibilities
Limitations	Motor disabilities

Table 5. 11 - Service EatWithYou

Name	EatWithYou
Actuation area	Be healthy
Care need	Diet planning
Description	We will help you with what to eat, making sure it is tasteful
Limitations	None

Table 5. 12 - Service Walking around

Name	Walking around
Actuation area	Feel useful
Care need	Recreational activities
Description	You will always find a new place with us.
Limitations	None

Table 5. 13 - Service We make it closer

Name	**We make it closer**
Actuation area	Feel useful
Care need	Recreational activities
Description	If you can dream it, we will make it
Limitations	Heart problems

Table 5. 14 – Service YoungBrains

Name	**YoungBrains**
Actuation area	Feel useful
Care need	Cognitive stimulation
Description	You don't have to play chess to be mentally active.
Limitations	None

Table 5. 15 – Service What are you looking for

Name	**What are you looking for?**
Actuation area	Feel useful
Care need	Recreational activities
Description	We will provide you the answer for your needs
Limitations	None

Table 5. 16 - Service NeverEatAlone

Name	**NeverEatAlone**
Actuation area	Independent living
Care need	Companionship
Description	No one should ever have to be alone
Limitations	None

Table 5. 17 – Service Forever

Name	**Forever**
Actuation area	Feel useful
Care need	Dating
Description	Every age is a good age to have a relationship
Limitations	None

Table 5. 18 - Service Let's go out

Name	**Let's go out**
Actuation area	Independent living
Care need	Companionship
Description	Don't stay at home. Let's go for a walk
Limitations	None

The considered Service Providers in the created scenarios are shown in Tables 5.19, 5.20, 5.21, 5.22 and 5.23:

Table 5. 19 - Service Provider FunHealth&Learn

Name	**FunHealth&Learn**
Associated services	• Aging with sport • What's on the agenda? • We make it closer • Forever

Table 5. 20 - Service Provider Here4U

Name	**Here4U**
Associated services	• Aging with sport • OnWheels • Mens sana corpore sano • YoungBrains

Table 5. 21 - Service Provider Ask for Us

Name	**Ask for Us**
Associated services	• Aging with sport • EatWithYou • We make it closer • Let's go out

Table 5. 22 - Service Provider Aging Nicely

Name	Aging Nicely
Associated services	• EatWithYou • Walking around • YoungBrains • What are you looking for?

Table 5. 23 - Service Provider ForeverYoung

Name	ForeverYoung
Associated services	• What's on the agenda? • NeverEatAlone • Forever • Let's go out

All the Service Providers will have to define the value of the requirements which are price, delivery time, technological usability, capability of personalization and SP reliability (Table 5.24).

Table 5. 24 - Service Providers requirement values

Service provider	Service	Requirement	Value
FunHealth&Learn	Aging with sport	Price	50
FunHealth&Learn	Aging with sport	Delivery time	48
FunHealth&Learn	Aging with sport	Technological usability	0.75
FunHealth&Learn	Aging with sport	Personalization	0.25
FunHealth&Learn	Aging with sport	SP reliability	5.00
FunHealth&Learn	What's on the agenda?	Price	200.00
FunHealth&Learn	What's on the agenda?	Delivery time	12.00
FunHealth&Learn	What's on the agenda?	Technological usability	0.25
FunHealth&Learn	What's on the agenda?	Personalization	1.00

FunHealth&Learn	What's on the agenda?	SP reliability	4.00
FunHealth&Learn	We make it closer	Price	100.00
FunHealth&Learn	We make it closer	Delivery time	96.00
FunHealth&Learn	We make it closer	Technological usability	0.25
FunHealth&Learn	We make it closer	Personalization	1.00
FunHealth&Learn	We make it closer	SP reliability	4.00
FunHealth&Learn	Forever	Price	25.00
FunHealth&Learn	Forever	Delivery time	72.00
FunHealth&Learn	Forever	Technological usability	0.75
FunHealth&Learn	Forever	Personalization	1.00
FunHealth&Learn	Forever	SP reliability	3.00
Here4U	Aging with sport	Price	80.00
Here4U	Aging with sport	Delivery time	48.00
Here4U	Aging with sport	Technological usability	1.00
Here4U	Aging with sport	Personalization	1.00
Here4U	Aging with sport	SP reliability	5.00
Here4U	OnWheels	Price	160.00
Here4U	OnWheels	Delivery time	96.00
Here4U	OnWheels	Technological usability	0.00
Here4U	OnWheels	Personalization	1.00
Here4U	OnWheels	SP reliability	5.00
Here4U	Mens sans corpore sano	Price	60.00
Here4U	Mens sans corpore sano	Delivery time	24.00
Here4U	Mens sans corpore sano	Technological usability	1.00
Here4U	Mens sans corpore sano	Personalization	1.00
Here4U	Mens sans corpore sano	SP reliability	3.00
Here4U	YoungBrains	Price	90.00
Here4U	YoungBrains	Delivery time	72.00
Here4U	YoungBrains	Technological usability	1.00
Here4U	YoungBrains	Personalization	0.25
Here4U	YoungBrains	SP reliability	4.50

Ask for Us	Aging with sport	Price	105.00
Ask for Us	Aging with sport	Delivery time	48.00
Ask for Us	Aging with sport	Technological usability	0.25
Ask for Us	Aging with sport	Personalization	1.00
Ask for Us	Aging with sport	SP reliability	3.50
Ask for Us	EatWithYou	Price	55.00
Ask for Us	EatWithYou	Delivery time	96.00
Ask for Us	EatWithYou	Technological usability	0.00
Ask for Us	EatWithYou	Personalization	0.50
Ask for Us	EatWithYou	SP reliability	5.00
Ask for Us	We make it closer	Price	55.00
Ask for Us	We make it closer	Delivery time	168.00
Ask for Us	We make it closer	Technological usability	0.50
Ask for Us	We make it closer	Personalization	0.75
Ask for Us	We make it closer	SP reliability	4.00
Ask for Us	Let’s go out	Price	30.00
Ask for Us	Let’s go out	Delivery time	24.00
Ask for Us	Let’s go out	Technological usability	0.25
Ask for Us	Let’s go out	Personalization	1.00
Ask for Us	Let’s go out	SP reliability	4.00
Aging Nicely	EatingWithYou	Delivery time	24.00
Aging Nicely	EatingWithYou	Technological usability	0.00
Aging Nicely	EatingWithYou	Personalization	0.25
Aging Nicely	EatingWithYou	SP reliability	3.50
Aging Nicely	Walking around	Price	90.00
Aging Nicely	Walking around	Delivery time	48.00
Aging Nicely	Walking around	Technological usability	0.50
Aging Nicely	Walking around	Personalization	1.00
Aging Nicely	Walking around	SP reliability	5.00
Aging Nicely	YoungBrains	Price	60.00
Aging Nicely	YoungBrains	Delivery time	72.00

Aging Nicely	YoungBrains	Technological usability	1.00
Aging Nicely	YoungBrains	Personalization	0.00
Aging Nicely	YoungBrains	SP reliability	4.50
Aging Nicely	What are you looking for?	Price	80.00
Aging Nicely	What are you looking for?	Delivery time	72.00
Aging Nicely	What are you looking for?	Technological usability	1.00
Aging Nicely	What are you looking for?	Personalization	0.75
Aging Nicely	What are you looking for?	SP reliability	3.00
ForeverYoung	What's on the agenda?	Price	200.00
ForeverYoung	What's on the agenda?	Delivery time	12.00
ForeverYoung	What's on the agenda?	Technological usability	0.25
ForeverYoung	What's on the agenda?	Personalization	0.50
ForeverYoung	What's on the agenda?	SP reliability	4.00
ForeverYoung	NeverEatAlone	Price	100.00
ForeverYoung	NeverEatAlone	Delivery time	48.00
ForeverYoung	NeverEatAlone	Technological usability	0.25
ForeverYoung	NeverEatAlone	Personalization	0.50
ForeverYoung	NeverEatAlone	SP reliability	3.00
ForeverYoung	Forever	Price	15.00
ForeverYoung	Forever	Delivery time	72.00
ForeverYoung	Forever	Technological usability	0.75
ForeverYoung	Forever	Personalization	1.00
ForeverYoung	Forever	SP reliability	4.00
ForeverYoung	Let’s go out	Price	150.00
ForeverYoung	Let’s go out	Delivery time	24.00
ForeverYoung	Let’s go out	Technological usability	0.75
ForeverYoung	Let’s go out	Personalization	0.25
ForeverYoung	Let’s go out	SP reliability	4.00

5.2 Functionalities Demonstration

As an example, a simple case will be shown. Let's imagine a scenario where the elderly named José Marques is registered in the system (Figure 5.1).

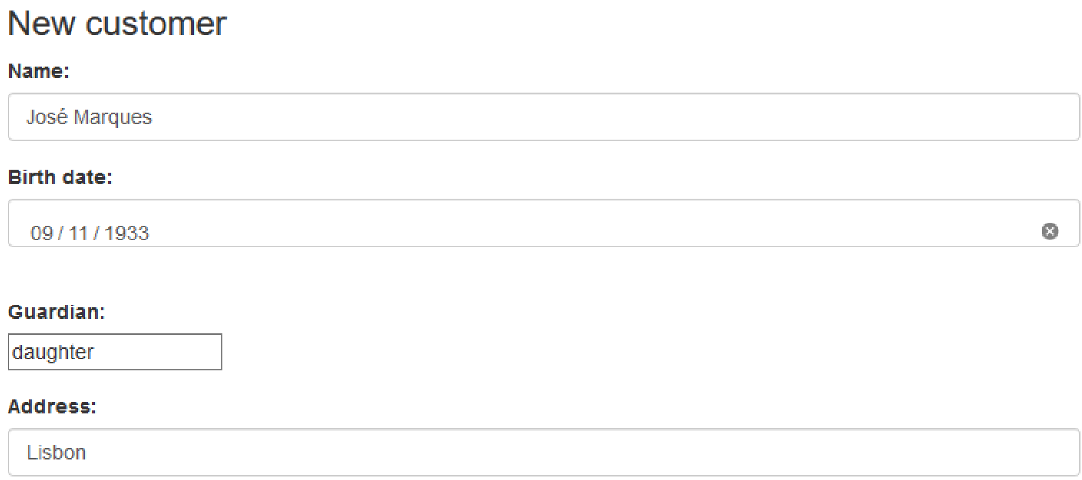
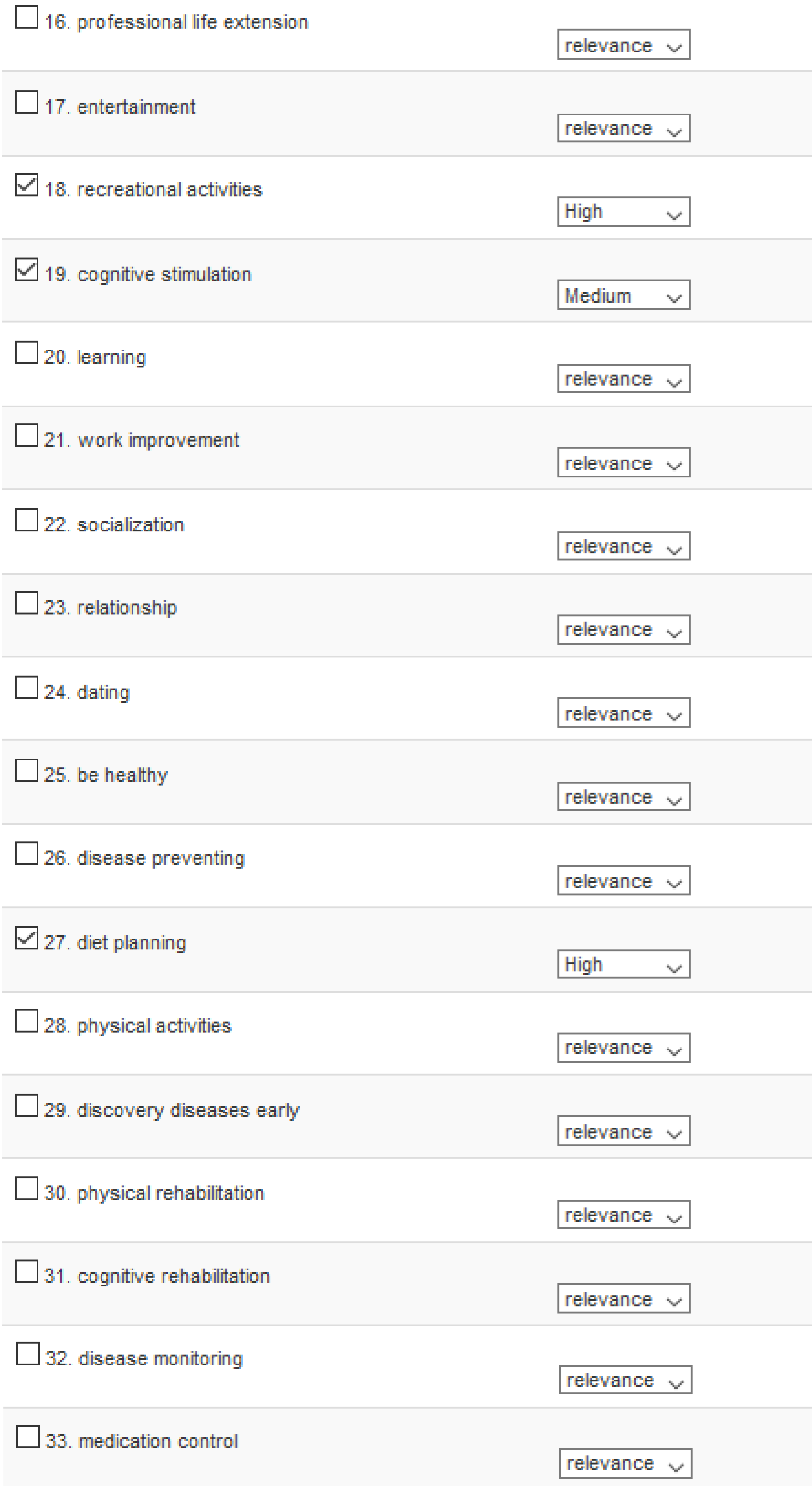


Figure 5. 1 - General information regarding José Marques

As mentioned, Mr. Marques has three care needs – recreational activities, cognitive stimulation, and diet planning (Figure 5.2) and five requirements, where two of them are a hard constraint (Figure 5.3).

Care Needs:

Care Need	Relevance
☐ 1. well being	relevance
☐ 2. independent living	relevance
☐ 3. security	relevance
☐ 4. safety	relevance
☐ 5. confort living	relevance
☐ 6. mobility	relevance
☐ 7. transportation	relevance
☐ 8. localization	relevance
☐ 9. cognitive support	relevance
☐ 10. emotional support	relevance
☐ 11. daily tasks monitoring	relevance
☐ 12. companionship	relevance
☐ 13. feel useful	relevance
☐ 14. occupation	relevance
☐ 15. monetary income	relevance



☐ 16. professional life extension	relevance
☐ 17. entertainment	relevance
☑ 18. recreational activities	High
☑ 19. cognitive stimulation	Medium
☐ 20. learning	relevance
☐ 21. work improvement	relevance
☐ 22. socialization	relevance
☐ 23. relationship	relevance
☐ 24. dating	relevance
☐ 25. be healthy	relevance
☐ 26. disease preventing	relevance
☑ 27. diet planning	High
☐ 28. physical activities	relevance
☐ 29. discovery diseases early	relevance
☐ 30. physical rehabilitation	relevance
☐ 31. cognitive rehabilitation	relevance
☐ 32. disease monitoring	relevance
☐ 33. medication control	relevance

Figure 5. 2 - Care needs regarding José Marques

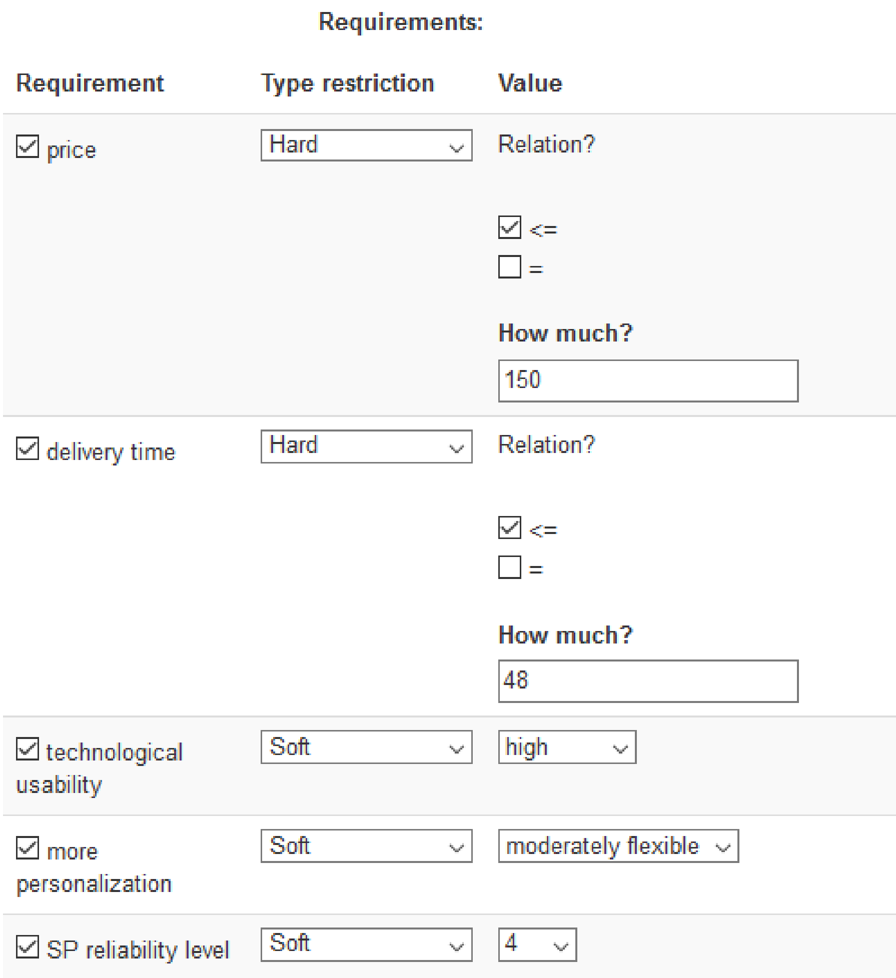


Figure 5. 3 - José Marques' requirements

In parallel, services and service providers must exist. As example, the addition of a service will be shown (Figure 5.4).

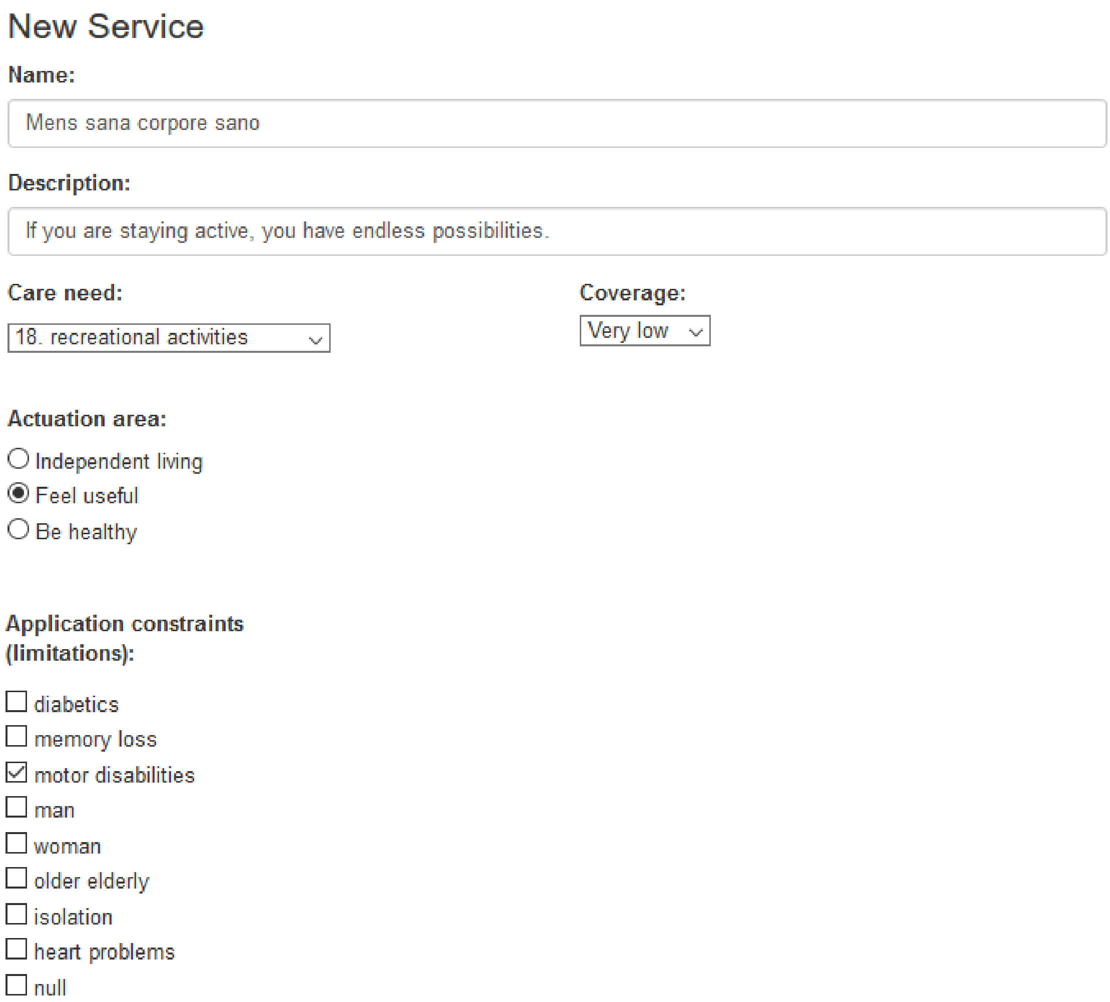


Figure 5. 4 - New service addition

The next step is for the ECE manager to add service providers that offer one or more services. For that, let´s assume that more than one service exists (Figure 5.5).

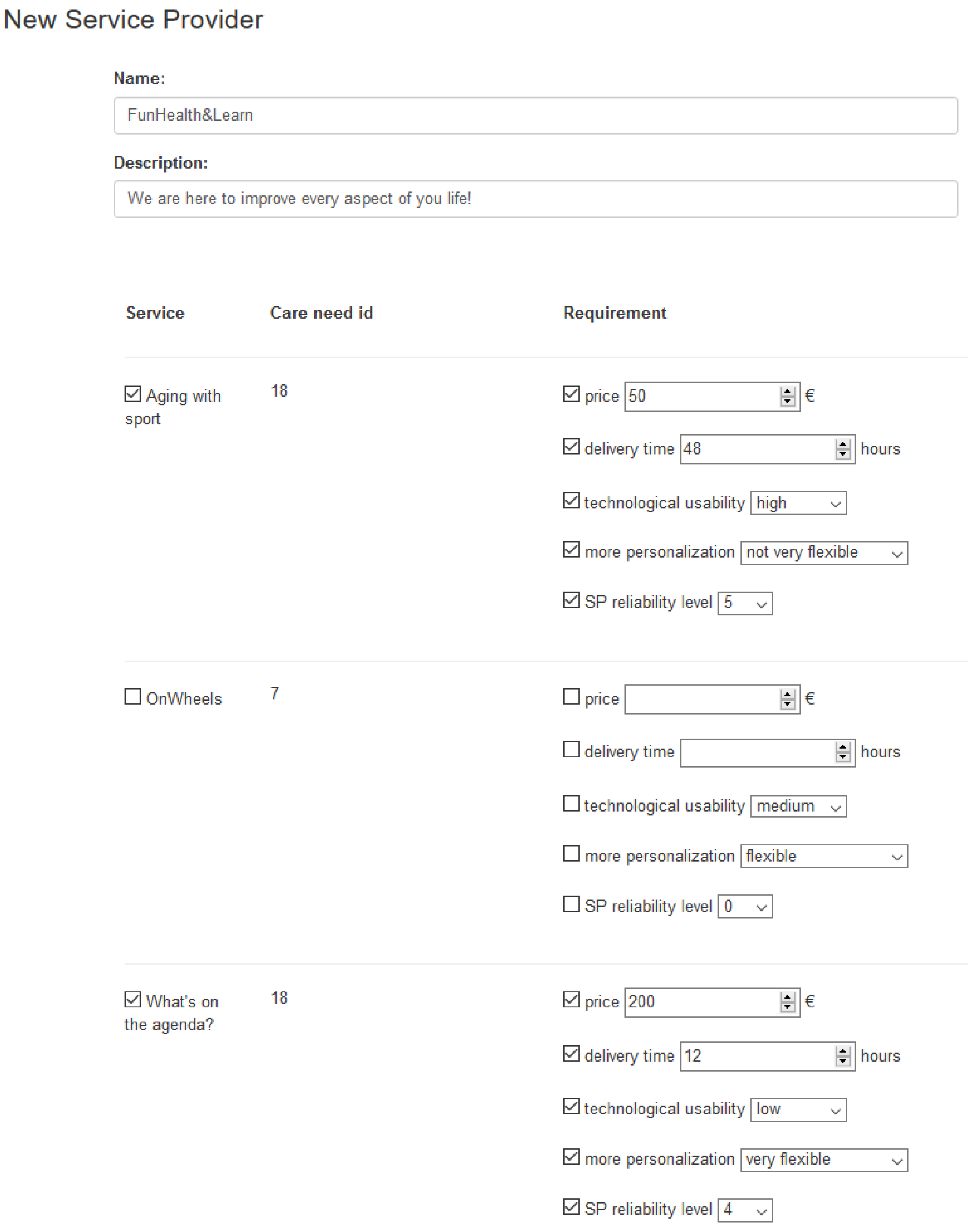


Figure 5. 5 - New service provider addition

Now, in order to run the algorithm, the manager has to identify what customer he wants to run it for. That's done by clicking on the button Customer Personalization and giving the customer's name, at the home page. (Figure 5.6).

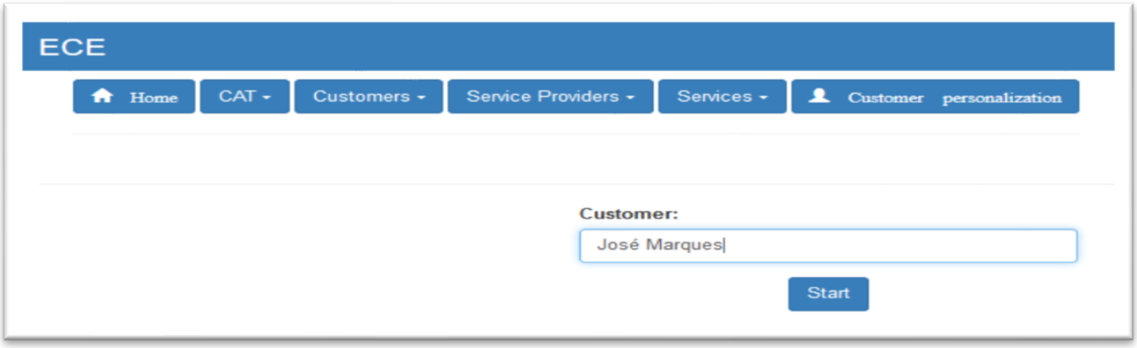


Figure 5. 6 - Customer Personalization

And then clicking at the Algorithm button (Figure 5.7).

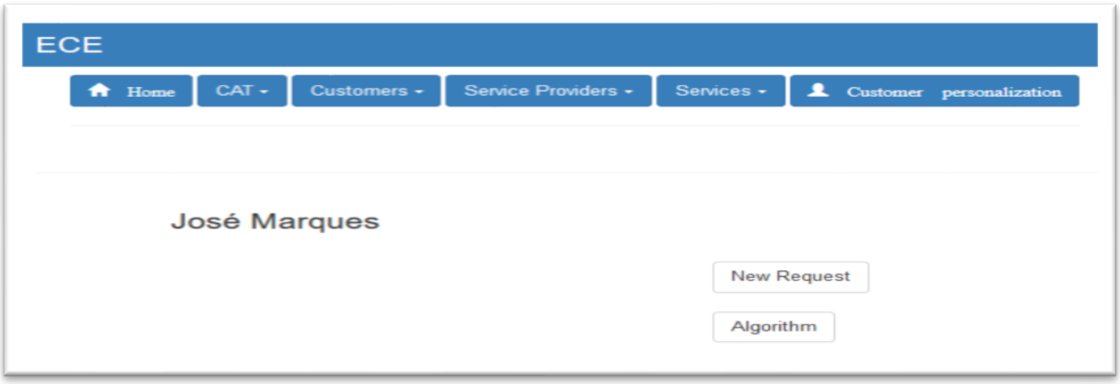


Figure 5. 7 - Run the algorithm

The solution is presented in Figures 5.8, 5.9, 5.10, 5.11 and 5.12.

Perfil

Personal information:
Customer: José Marques
Birth date: 1933-11-09
Guardian: daughter
Address: Lisbon

Care needs:
recreational activities	relevance: 0.75
cognitive stimulation	relevance: 0.50
diet planning	relevance: 0.75

Requirements:
price	constraint type: hard	<=	value: 150.00
delivery time	constraint type: hard	<=	value: 48.00
technological usability	constraint type: soft	value: 0.75
more personalization	constraint type: soft	value: 0.50
SP reliability level	constraint type: soft	value: 4.00

Limitations:
diabetics
memory loss

ICT resources:
wi-fi
insurance

Characteristic:	Status:	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

Figure 5. 8 - Customer's profile presentation

Solution based on Adherence maximization criteria:
total AD: 1.58
total cost benefit ratio: 2.12
total number of services: 8

Solution based on cost benefit ratio maximization criteria:
total AD: 1.35
total cost benefit ratio: 2.39
total number of services: 8

Solution based on service providers minimization criteria:
total AD: 1.58
total cost benefit ratio: 1.88
total number of services: 12

Solutions

care need	service name	service provider name	AD	cost	cost benefit ratio	n of SE
recreational activities	Mens sana corpore sano	Here4U	0.39	60	0.65	2
recreational activities	Walking around	Aging Nicely	0.62	90	0.69	4
recreational activities	We make it closer	FunHealth&Learn	0.39	100	0.39	1
recreational activities	We make it closer	Ask for Us	0.39	55	0.71	2
recreational activities	What are you looking for?	Aging Nicely	0.57	80	0.71	4
cognitive stimulation	YoungBrains	Here4U	0.45	90	0.50	2
cognitive stimulation	YoungBrains	Aging Nicely	0.45	60	0.75	4
diet planning	EatWithYou	Ask for Us	0.51	55	0.93	2
diet planning	EatWithYou	Aging Nicely	0.51	115	0.44	4

Solution based on Adherence maximization criteria:

For care need '**recreational activities**' - Service '**Walking around**' provided by the service provider '**Aging Nicely**'
For care need '**cognitive stimulation**' - Service '**YoungBrains**' provided by the service provider '**Here4U**'
For care need '**diet planning**' - Service '**EatWithYou**' provided by the service provider '**Ask for Us**'

Solution based on cost benefit ratio maximization criteria:

For care need '**recreational activities**' - Service '**We make it closer**' provided by the service provider '**Ask for Us**'
For care need '**cognitive stimulation**' - Service '**YoungBrains**' provided by the service provider '**Aging Nicely**'
For care need '**diet planning**' - Service '**EatWithYou**' provided by the service provider '**Ask for Us**'

Solution based on service providers minimization criteria:

For care need '**recreational activities**' - Service '**Walking around**' provided by the service provider '**Aging Nicely**'
For care need '**cognitive stimulation**' - Service '**YoungBrains**' provided by the service provider '**Aging Nicely**'
For care need '**diet planning**' - Service '**EatWithYou**' provided by the service provider '**Aging Nicely**'

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Figure 5. 9 - General solution

Solutions for Adherence Maximization

care need	service name	service provider name	AD	cost	cost benefit ratio	number of services
recreational activities	Walking around	Aging Nicely	0.62	90	0.69	4
recreational activities	What are you looking for?	Aging Nicely	0.57	80	0.71	4
diet planning	EatWithYou	Ask for Us	0.51	55	0.93	2
diet planning	EatWithYou	Aging Nicely	0.51	115	0.44	4
cognitive stimulation	YoungBrains	Here4U	0.45	90	0.50	2
cognitive stimulation	YoungBrains	Aging Nicely	0.45	60	0.75	4
recreational activities	Mens sana corpore sano	Here4U	0.39	60	0.65	2
recreational activities	We make it closer	FunHealth&Learn	0.39	100	0.39	1
recreational activities	We make it closer	Ask for Us	0.39	55	0.71	2

Figure 5. 10 - Adherence maximization criteria solution - PDF

Solutions for cost benefit ratio

care need	service name	service provider name	AD	cost	cost benefit ratio	number of services
diet planning	EatWithYou	Ask for Us	0.51	55	0.93	2
cognitive stimulation	YoungBrains	Aging Nicely	0.45	60	0.75	4
recreational activities	We make it closer	Ask for Us	0.39	55	0.71	2
recreational activities	What are you looking for?	Aging Nicely	0.57	80	0.71	4
recreational activities	Walking around	Aging Nicely	0.62	90	0.69	4
recreational activities	Mens sana corpore sano	Here4U	0.39	60	0.65	2
cognitive stimulation	YoungBrains	Here4U	0.45	90	0.50	2
diet planning	EatWithYou	Aging Nicely	0.51	115	0.44	4
recreational activities	We make it closer	FunHealth&Learn	0.39	100	0.39	1

Figure 5. 11 - Cost-benefit maximization criteria solution

Solutions for number of services maximization

care need	service name	service provider name	AD	cost	cost benefit ratio	number of services
recreational activities	Walking around	Aging Nicely	0.62	90	0.69	4
recreational activities	What are you looking for?	Aging Nicely	0.57	80	0.71	4
cognitive stimulation	YoungBrains	Aging Nicely	0.45	60	0.75	4
diet planning	EatWithYou	Aging Nicely	0.51	115	0.44	4
recreational activities	Mens sana corpore sano	Here4U	0.39	60	0.65	2
recreational activities	We make it closer	Ask for Us	0.39	55	0.71	2
cognitive stimulation	YoungBrains	Here4U	0.45	90	0.50	2
diet planning	EatWithYou	Ask for Us	0.51	55	0.93	2
recreational activities	We make it closer	FunHealth&Learn	0.39	100	0.39	1

Figure 5. 12 - Service maximization criteria solution

Based on the Adherence maximization criterion, with 1.58 total adherence and 2.12 total cost benefit ratio values, we have, for each care need, the services and service providers advised. For instance, for the cognitive stimulation care need, it is suggested the service Young Brains, delivered by the Here4U provider.

In order to understand where these values come from, let's pay attention to the total adherence, according to the cost benefit ratio maximization criterion. As we want to use the cost benefit ratio maximization criterion, we have to look at the respective column. For each care need, we'll have to choose the higher value from that column. And, as we want the total adherence, we have to get the respective AD value. Concretely, for the recreational activities care need, the maximum value of the cost benefit ratio is 0.71, so the value that we are looking for is the respective AD, that is, 0.39. For the cognitive stimulation, the maximum cost benefit ratio value is 0.75, so, 0.45 is the value we care about. We do the same for the third care need, the maximum cost benefit ratio is 0.93, so the value that matters is 0.51. If we add the three AD values, we'll get the 1.35 (0.39 + 0.45 + 0.51 = 1.35). If we wanted the cost benefit ratio total, we would add the maximum cost benefit ratio values of each care need (0.71 + 0.75 + 0.93 = 2.39).

The Number of Services column is important because an elderly may want to deal with as few Service Providers as possible. He may want to contact with just one person and get a kind of turnkey service, where that person solves any subject that might appear.

The ECE provides the results for the conditions provided. The first pieces of information it provides are the ones that characterize the customer to whom the solution is being calculated for. Afterwards it shows the summary of the solutions that were obtained, mentioning the criteria, the value for the total adherence, for the total cost benefit ratio and for the total number of services. Then, it provides the specifics for each solution based on the different criteria, meaning that for each criteria it will show, regarding to what care need is it referring to, the service that answers it and the service provider that will do it, and it will also have a link to convert the results into a pdf file. Finally, it will provide different tables, one for each criteria, in which it will provide the detailed information for each case.

For each of Mr. Marques care needs, the service providers Aging Nicely, Here4U and Ask for Us are the ones that perform better under the Adherence maximization criteria, which means those are the ones that are closer to the customer's requirements. Regarding the cost-benefit ratio criteria, the service providers Ask for Us and Aging Nicely are the ones who present better results, which indicates that those are the cheapest ones. In the last criteria, the service provider Aging Nicely is the one that excels because it is the one that will allow for least service providers to fulfil the customer needs.

In order to demonstrate the functionality of the ECE, a new example is demonstrated. In this case, the customer chosen is Mrs. Teresa Costa. In the following images, similar to what happened before, the profile of Mrs. Costa and its general solution is illustrated in Figures 5.13 and 5.14.

Perfil

Personal information:
Customer: Teresa Costa
Birth date: 1940-06-02
Guardian:
Address: Aveiro
Everyday local address: Lisbon

Care needs:
transportation | relevance: 0.50
recreational activities | relevance: 0.25
cognitive stimulation | relevance: 0.75

Requirements:
price | constraint type: soft | <= | value: 100.00
delivery time | constraint type: soft | <= | value: 24.00
technological usability | constraint type: hard | value: 0.00
more personalization | constraint type: soft | value: 0.75
SP reliability level | constraint type: soft | value: 4.50

Limitations:
motor disabilities
isolation

ICT resources:
wi-fi
mobile phone

Characteristic:	Status:	Relevance:
independent living	not_active	very_important
culture	active	important
religion	highly_active	not_important
social	not_active	very_important
technological	active	important
recreational	highly_active	not_important
financial	not_active	very_important
friendship	active	important
household	highly_active	not_important
community	not_active	very_important
love	active	important
educational	highly_active	not_important
professional	not_active	very_important
health	active	important
family	highly_active	not_important

Figure 5. 13 - Customer Teresa Costa's profile

Solution based on Adherence maximization criteria:
total AD: 1.45
total cost benefit ratio: 1.93
total number of services: 9

Solution based on cost benefit ratio maximization criteria:
total AD: 1.45
total cost benefit ratio: 2.17
total number of services: 9

Solution based on service providers minimization criteria:
total AD: 1.45
total cost benefit ratio: 1.93
total number of services: 9

Solutions

care need	service name	service provider name	AD	cost	cost benefit ratio	n of SE
transportation	OnWheels	Here4U	0.43	160	0.27	3
recreational activities	Aging with sport	FunHealth&Learn	0.59	50	1.18	3
recreational activities	Aging with sport	Here4U	0.59	80	0.74	3
recreational activities	Aging with sport	Ask for Us	0.59	105	0.56	2
recreational activities	What's on the agenda?	FunHealth&Learn	0.49	200	0.25	3
recreational activities	What's on the agenda?	ForeverYoung	0.49	200	0.25	1
recreational activities	Walking around	Aging Nicely	0.59	90	0.66	3
recreational activities	We make it closer	FunHealth&Learn	0.39	100	0.39	3
recreational activities	We make it closer	Ask for Us	0.39	55	0.71	2
recreational activities	What are you looking for?	Aging Nicely	0.54	80	0.68	3
cognitive stimulation	YoungBrains	Here4U	0.43	90	0.48	3
cognitive stimulation	YoungBrains	Aging Nicely	0.43	60	0.72	3

Solution based on Adherence maximization criteria:

For care need '**transportation**' - Service '**OnWheels**' provided by the service provider '**Here4U**'
For care need '**recreational activities**' - Service '**Aging with sport**' provided by the service provider '**FunHealth&Learn**'
For care need '**cognitive stimulation**' - Service '**YoungBrains**' provided by the service provider '**Here4U**'

Solution based on cost benefit ratio maximization criteria:

For care need '**transportation**' - Service '**OnWheels**' provided by the service provider '**Here4U**'
For care need '**recreational activities**' - Service '**Aging with sport**' provided by the service provider '**FunHealth&Learn**'
For care need '**cognitive stimulation**' - Service '**YoungBrains**' provided by the service provider '**Aging Nicely**'

Solution based on service providers minimization criteria:

For care need '**transportation**' - Service '**OnWheels**' provided by the service provider '**Here4U**'
For care need '**recreational activities**' - Service '**Aging with sport**' provided by the service provider '**FunHealth&Learn**'
For care need '**cognitive stimulation**' - Service '**YoungBrains**' provided by the service provider '**Here4U**'

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Figure 5. 14 - Customer Teresa Costa's general solution

The results produced by the execution of the algorithm for Mrs. Costa are very different from the ones produced by the request of Mr. José Marques, as it was expected. Since they have different care needs and different requirements, the solution produced by the algorithm suggests different service providers for each case.

Even in the case of the same care need, which happens because both Mr. Marques and Mrs. Costa share recreational activities as a care need, the solution provided is different since they both have different requirements.

Afterwards, for the case of Mrs. Costa, a new service provider was added to the ECE, as illustrated in Table 5.25 in order to find out if it had any implications on the solution proposed, as shown at Figure 5.15.

Table 5. 25 - New Service Provider

Name	**The magic van**
Associated services	• OnWheels

Solution based on Adherence maximization criteria:
total AD: 1.48
total cost benefit ratio: 1.96
total number of services: 9

Solution based on cost benefit ratio maximization criteria:
total AD: 1.48
total cost benefit ratio: 2.42
total number of services: 7

Solution based on service providers minimization criteria:
total AD: 1.48
total cost benefit ratio: 1.96
total number of services: 9

Figure 5. 15 - Teresa Costa's general solution after the addition of a Service Provider

Solutions

care need	service name	service provider name	AD	cost	cost benefit ratio	n of SE
transportation	OnWheels	Here4U	0.44	160	0.27	3
transportation	OnWheels	The magic van	0.44	90	0.49	1
recreational activities	Aging with sport	FunHealth&Learn	0.60	50	1.20	3
recreational activities	Aging with sport	Here4U	0.60	80	0.75	3
recreational activities	Aging with sport	Ask for Us	0.60	105	0.57	2
recreational activities	What's on the agenda?	FunHealth&Learn	0.50	200	0.25	3
recreational activities	What's on the agenda?	ForeverYoung	0.50	200	0.25	1
recreational activities	Walking around	Aging Nicely	0.60	90	0.67	3
recreational activities	We make it closer	FunHealth&Learn	0.39	100	0.39	3
recreational activities	We make it closer	Ask for Us	0.39	55	0.71	2
recreational activities	What are you looking for?	Aging Nicely	0.55	80	0.69	3
cognitive stimulation	YoungBrains	Here4U	0.44	90	0.49	3
cognitive stimulation	YoungBrains	Aging Nicely	0.44	60	0.73	3

Solution based on Adherence maximization criteria:

For care need '**transportation**' - Service '**OnWheels**' provided by the service provider '**Here4U**'
For care need '**recreational activities**' - Service '**Aging with sport**' provided by the service provider '**FunHealth&Learn**'
For care need '**cognitive stimulation**' - Service '**YoungBrains**' provided by the service provider '**Here4U**'

Solution based on cost benefit ratio maximization criteria:

For care need '**transportation**' - Service '**OnWheels**' provided by the service provider '**The magic van**'
For care need '**recreational activities**' - Service '**Aging with sport**' provided by the service provider '**FunHealth&Learn**'
For care need '**cognitive stimulation**' - Service '**YoungBrains**' provided by the service provider '**Aging Nicely**'

Solution based on service providers minimization criteria:

For care need '**transportation**' - Service '**OnWheels**' provided by the service provider '**Here4U**'
For care need '**recreational activities**' - Service '**Aging with sport**' provided by the service provider '**FunHealth&Learn**'
For care need '**cognitive stimulation**' - Service '**YoungBrains**' provided by the service provider '**Here4U**'

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Figure 5. 15 (cont.) - Teresa Costa's general solution after the addition of a Service Provider

After executing again the algorithm, with the information related to a new service provider, the general solution improves for each criteria. As it can be seen, for all the pre-defined criteria, the value for the total adherence increases in the solution, as well as the value for the cost-benefit ratio. It means that the new service provider allows for a solution that is more suited for the needs of Mrs. Costa.

The algorithm will provide the answers to the customer care needs based on the information the ecosystem has and on the pre-defined criteria. This means that if a new service provider is added or changed, or even a customer care need is changed, when the algorithm is executed, it is possible to get different results. It also means that a certain service provider may be the best solution under one the adherence maximization criteria but at the same time, under a different criteria, such as cost-benefit ratio, it can be one of the worst. Even though the application of the algorithm is meant to provide the most appropriate answer to the customer's care needs, given the information it has, those answers are not mandatory but simply suggestions to the customer.

6

Conclusions and future work

We face a new reality today. Not that long ago the unspoken rule was that people would die young and every year many births would take place. However, nowadays, we are facing a new shape in the demographic pyramid of the world population since there are fewer people being born and the elderly are dying each time later.

The elderly population is expected to grow largely in the next few years so, in order to tackle with the upcoming reality, new paths must be drawn to deal with the elderly necessities instead of the young people needs. For that to be possible, we must first acknowledge that the definition of an elderly person needs to surpass age as a vital point but considers now its interest in having a healthy life, knowing the person interests, goals and specific needs are very important to adequately define what taking care of an elderly requires.

In an attempt to address these questions, Baldissera & Camarinha-Matos (2018a) proposed a concept of a Business Ecosystem in which a manager would gather the information from different elderly people (known as customers) and from different services and service providers with its characteristics. Then, according to criteria defined by the customer, it would run an algorithm that would provide different solutions for the customer to choose from. The present work arises as a follow up of that work.

Socially speaking, approaching this new reality of elderly people care needs, requires some concepts to be fully defined so that a common ground can be build and the same language can be used. For instance, even though cooperation and collaboration are often used as synonyms, they are, in fact different since cooperation implies information exchange, adjustments of activities and sharing resources for accomplishing compatible goals. Collaboration, on the other hand, is a process that involves a much deeper ability to work together since it means that entities share information, resources and responsibilities to jointly plan, implement and evaluate a program of action to achieve a mutual objective. As far as this work is concerned, it is also important to understand the concept of a collaborative network. An agreement between various entities, such as organizations and people, that are broadly autonomous, geographically dispersed and heterogeneous in many aspects, but that collaborate to accomplish equal or congruent goals and whose communications are sustained by computer network constitute a collaborative network. A Business Ecosystem is a specific type of a Collaborative Network. It is based on the characteristic mechanisms of biological ecosystems, as these networks try to conserve the specificities, tradition and culture of the local and frequently benefit from government incentives.

The goal of this work is, thus, to start to provide an answer to the question proposed by Baldissera & Camarinha-Matos (2018a), of how to provide personalized collaborative care services for elderly in an effective and reliable way.

For that to happen, a Business Ecosystem, namely an Elderly Care Ecosystem (ECE) was developed using Laravel.

The first step in using the ECE is to provide information to the ECE manager. A customer is expected to provide both personal information and details in requirements, namely to what areas do they belong (living healthy or staying active, for instance) and rate how important they are. The person responsible for managing the ECE will be responsible for adding the services that will answer to the customer's request. Finally, a service provider is expected to provide information regarding the services that provides and also about some characteristics like price and how adaptable can it be.

After all that information is gathered, the manager can run an algorithm which, in turn, will provide the customer with several answers to meet the requirements that were previously specified according to different criteria like price, adherence or the usage of fewer service providers.

In the present work, a scenario was developed where the criteria for the different solutions were Adherence Maximization, cost-benefit ratio and services maximization. The application of the ECE's algorithm starts by scanning from every pair service-service provider so that only the ones that meet the specified customer needs are left to be calculated for the closeness and adherence.

Afterwards, the adherence is calculated to see how close the service providers to the customer needs are. The final step of the algorithm application are the different tables that are produced. The first one ranks the pairs service-service provider for the highest value of Adherence. Adherence is a coefficient that defines how close is the service provider's offer to the customer's need and, in the case of customer named José Marques who was used as example, using the adherence maximization criterion, the Service Provider Ageing Nicely, and service Walking around have the highest value for adherence, for recreational activities care need. For care need cognitive stimulation is the service YoungBrains, available from the Here4U provider and, for diet planning care need, the EatWithYou service and the Ask for Us provider are the ones with the highest value.

The cost-benefit ratio evaluates the price of the service provider against how much the customer is willing to spend to get the services. For this criterion, for instance for the recreational activities care need, the highest ranked solution would be the service provider Ask for Us with the service We make it closer, and so on.

The final criteria, services maximization, evaluates how many services are needed to meet the customer's requirements, because there is the possibility for a person to favor a solution that requires less service providers because of the confusion caused by many different providers.

In most cases, it will not be possible for a single service provider to respond to all the customer's care needs, so it is going to be needed to combine multiple service providers.

There is, however, room to improve the present work, since it is only the beginning of the answer to the question of how to provide personalized collaborative care services for elderly in an effective and reliable way. As possible suggestions for future works, the enhancement of the capabilities of the ECE, making it possible for one service to cover multiple care needs. The other possibility would be to improve the interface to make it more user friendly and understandable, considering it is something meant to be used by the elderly who, traditionally are not the most technically agile. Nevertheless, the developed work appears to demonstrate that the proposed algorithm by Baldissera & Camarinha-Matos (2018a), can provide consistent results.

7

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