Evaluating the Applicability and Utility of an Elderly Care Ecosystem

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Abstract. The improvement of life expectancy and the decline of total fertility rate worldwide have been key factors for the increasing percentage of the elderly population in the society. Aging comes with several personal needs, which require multiple care services specially tailored (personalized) for each individual. As these needs change throughout life, current services need to adapt (evolve) to reflect new requirements. Advances on collaborative networks for elderly care suggest the integration of services from multiple providers, encouraging collaboration as a way to provide better personalized and evolutionary services. This approach requires a support system to manage the personalized and evolving services for elderly care. In this paper, we present the *Elderly Care Ecosystem* (ECE) framework. ECE is a system designed to support the personalization and evolution of elderly care services following the principles of collaborative networks. To show the feasibility of our approach, we developed a prototype of ECE and evaluated it empirically using the technology acceptance model. Evaluation results are then presented and discussed.

Keywords: Collaborative business services · ICT and ageing · Elderly Care Ecosystem · Technology acceptance model

1 Introduction

Society is getting older due to the increase in average life expectancy from 62 to 74 years. This age group represents a bigger slice in the total number of the population. This situation also can be noticed with the increase of the world average age, from 24 years old in 1950 to 29 in 2010, 32 in 2025 and 36 in 2050 [1]. This poses tough challenges to the society on how to provide effective care services that fit the needs of each individual and adjust to the evolution of those needs.

To cope with the needs of this new context, a collaborative Elderly Care Ecosystem (ECE) based in the Collaborative Networks Discipline [4] and following a user-centric perspective, is proposed and briefly presented. ECE involves four main elements (customer, care needs, service, and service provider), four subsystems (ECE Manager, ECE Information, ECE Personalization and ECE evolution) and it is operationalized into three phases (Preparation, Execution, and Monitoring).

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In this paper, an implementation prototype is described and the evaluation of the ECE framework is performed using an adapted version of the Technology Acceptance Model (TAM).

The remainder of this article is organized as follows: the adopted research method is introduced in Sect. 2; the Elderly Care Ecosystem and its methods for service personalization and evolution are introduced in Sect. 3; Sect. 4 presents the developed ECE software prototype; the conceptual framework evaluation by the adapted TAM is introduced in Sect. 5. Finally, the conclusions and future work are presented in Sect. 6.

2 Adopted Research Method

Frequently, a mix of methods is used to validate the expected results of a research work [2]. In particular, the Constructive Research method [3] can help validating applied research in the area of design science. Validation in design science is performed by building one or more artefacts that solve a domain problem, in order to create knowledge on how the problem can be solved, and show how the solution is new or better than the previous ones.

The ECE framework and methods are evaluated in terms of their applicability and utility considering an adaptation of the Technology Acceptance Model (TAM) methodology [5]. TAM is focused on the intention to use a new technology or innovation and was specifically developed to explain and predict the acceptance of information and communication technologies by potential users.

The evaluation of the perceived utility and applicability of our approach is done through a survey with professional experts in the health and elderly care areas. The interviews were structured in face-to-face meetings following four steps:

1. Introduction: a brief presentation was given to the participants to explain the goals of the research and its details, including the underlying PhD research project and the protocol involving the survey.
2. ECE tutorial: participants watched a brief video tutorial describing the main features of the ECE (personalization and evolution processes) and applications of the ECE using different illustrative examples.
3. Demonstration of the ECE prototype: a brief overview of the prototype was shown to the participants, showing its main functionalities.
4. Survey application: the participants were invited to respond to the survey, which was elaborated according to TAM.

3 Elderly Care Ecosystem Conceptual Framework

An Elderly Care Ecosystem represents a particular case of a Collaborative Business Ecosystem. Our concept characterizes an ECE as an "Elderly Care Collaborative Network" which involves four main elements (more detailed in [6]): Customers (CU): representing the seniors that consume the services provided by virtual organizations (Vos) of providers in ECE. Care needs (CA): representing the care needs of seniors;

these care needs are organized on a taxonomy of care need goals used in a specific ECE. Services (SE): representing the group of services available in ECE. Service Providers (SP): representing a set of organizations (virtual or physical) that provide ECE care services. The ECE environment domain diagram (presented in Fig. 1) highlights the ECE subsystems:

The ECE Manager System (ECE_{ms}) represents the component that administers the ECE environment comprising management entities of ECE in the collaborative network environment. The main elements involve the roles of manager, broker, virtual organizations (VO), coordinator and planer of Vos. The ECE Information System (ECE_{IS}) is the component that maintains the ECE entities and objects, namely service providers, services, care needs and taxonomy, and customers. The ECE Personalization System (ECE_{PS}) involves the personalization subsystem that identifies the customer profile and ranks potential solutions (services and respective service providers) to attend the requirements. The Service Composition and Personalization Environment (SCoPE) method is presented in Sect. 3.1. ECE Evolution System (ECE_{EV}) identifies opportunities for service evolution to a new context and supports that evolution (SEvol method), which is briefly presented in Sect. 3.2.

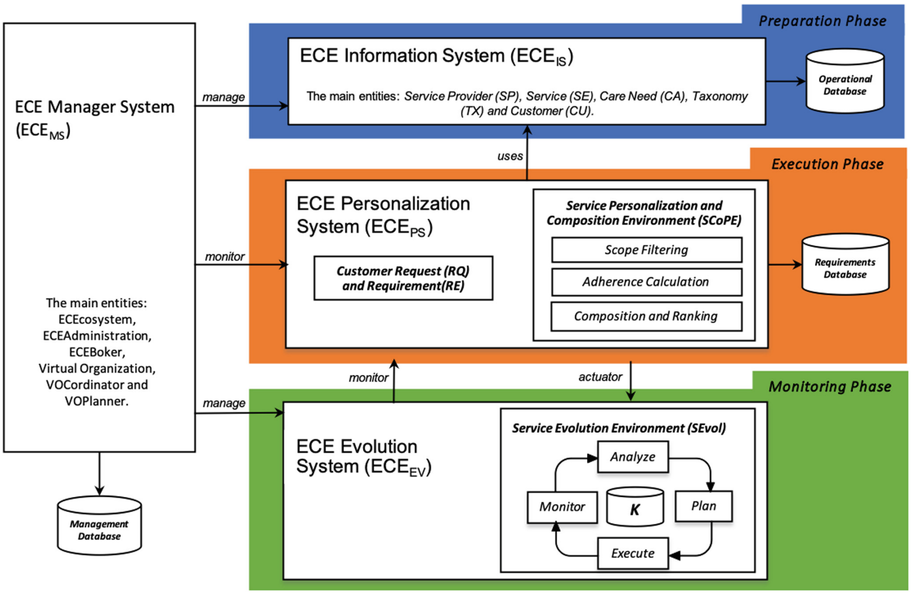

Fig. 1. ECE conceptual framework domain diagram

Considering ECE operationalization, three phases are performed: Preparation, which is responsible for the ECE creation and definition of its rules and functionalities. Execution, which identifies the customer request and its requirements, and the process of composition and personalization of ECE care services are executed. Monitoring, which supports the ECE care service evolution and monitoring in the personalized solution.

3.1 Service Composition and Personalization Environment (SCoPE) Method

The SCoPE method comprises three steps: (1) Scope Filtering, (2) Service Adherence Calculation, and (3) Service Composition and Ranking. Figure 2 shows the SCoPE general approach and these steps.

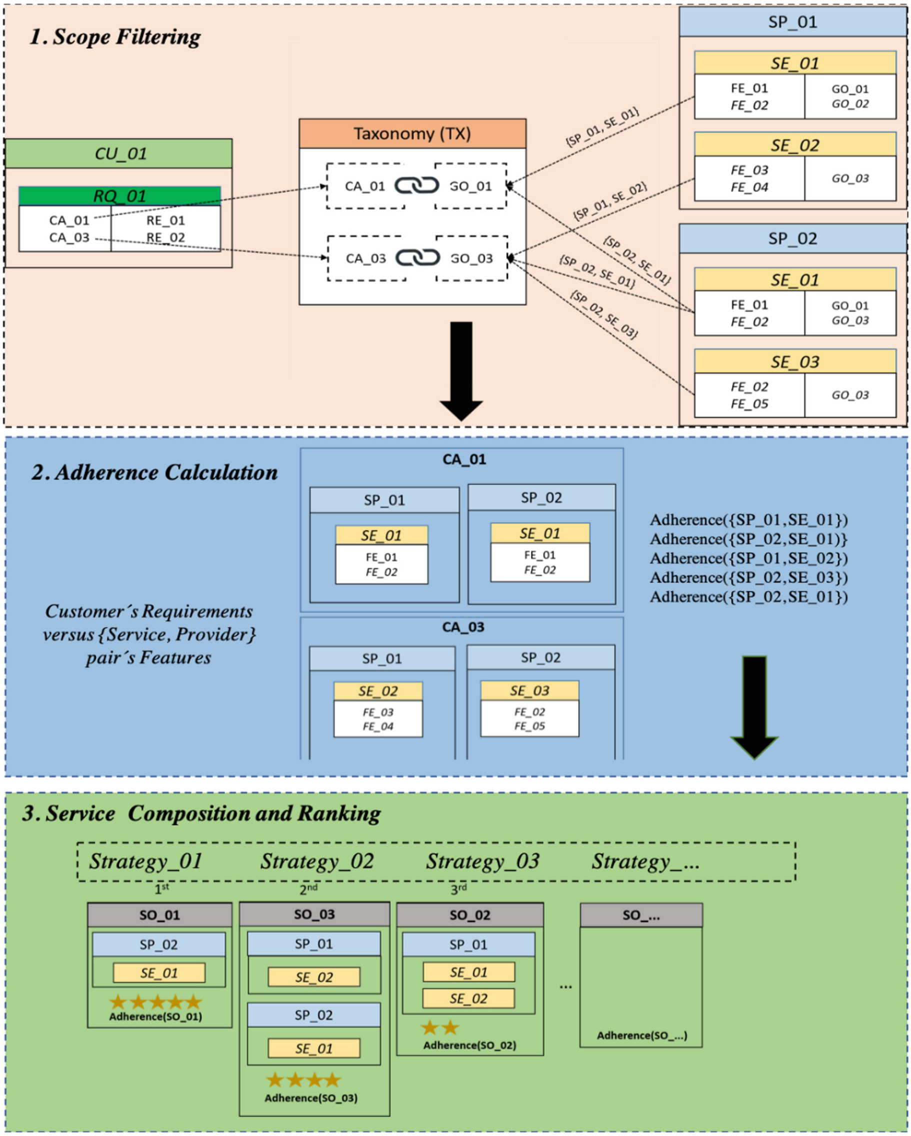

Fig. 2. SCoPE method overview

The first step (*Scope Filtering*) 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*, which is meant to determine a compatibility index relating the customer's profile, requirements and priorities to the provider's characteristics and care services features. 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 of obtaining 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 three coefficients: Closeness (CL), Partial Adherence (PA), and Adherence (AD).

Since it is aimed to provide 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.

The second calculated coefficient is the partial adherence. It starts with the calculation of G, which is the average of the closeness of all care needs. It then combines G 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 is calculated. The CO is defined 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.

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 care need (adherence AD).

In this final step (*Service Composition and Ranking*), the {service, provider} pairs that have been evaluated and which adherences were calculated are rated and there is a suggestion of composition of services based on selected strategies. The solution is presented in terms of lower cost, better cost/benefit ratio and minimization of the number of providers. More details about the SCoPE algorithm and application cases can be found in [7].

3.2 Service Evolution (SEvol) Method

Following the adaptive systems approach, the SEvol method is based on a control loop composed of four main phases: (1) *Monitor:* monitoring events that occur in the surrounding physical and social context; (2) *Analyze*: analyzing monitored data against solution requirements to identify need of adaptation; (3) *Plan*: devising an evolution strategy that reconciles current solution with a new customer's context; and (4) *Execute*: enacting such strategy while minimizing disturbances caused by suggested solutions. These phases are showed and exemplified in Fig. 3.

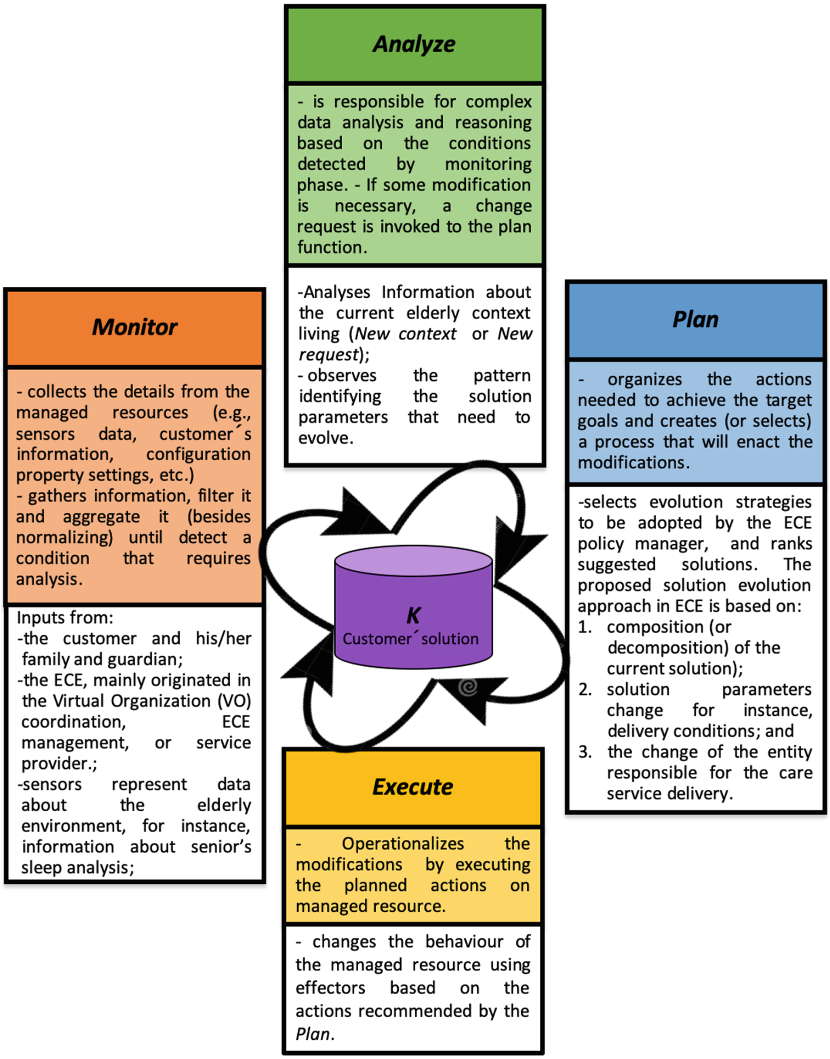

Fig. 3. SEvol method overview

4 ECE Software Prototype

An ECE software prototype was implemented with the necessary information to demonstrate basic operations of the ECE (inclusion, exclusion, customer search, care needs, services, services providers) and the process of personalization and evolution of care services.

The programming language environment used to develop the ECE prototype was *PHP* by *Laravel* Framework and *Laragon* web service [8]. Laravel is a free, open-source *PHP* web framework intended for web app development that follows the model-view-controller (MVC) architectural pattern. Some 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 [8]. *Laragon* is aimed at building and managing web applications and it is focused on performance [8].

4.1 Preparation Phase: ECE Setup and Configuration

Figure 4 presents the use case diagram of the main actors and processes of the prototype setup and configuration involving the ECE_{ms} and ECE_{IS}. In this stage, the validation of the elements to start the execution process is done. There is at least one item in each profile (customer, taxonomy, service provider, and service) that must be registered.

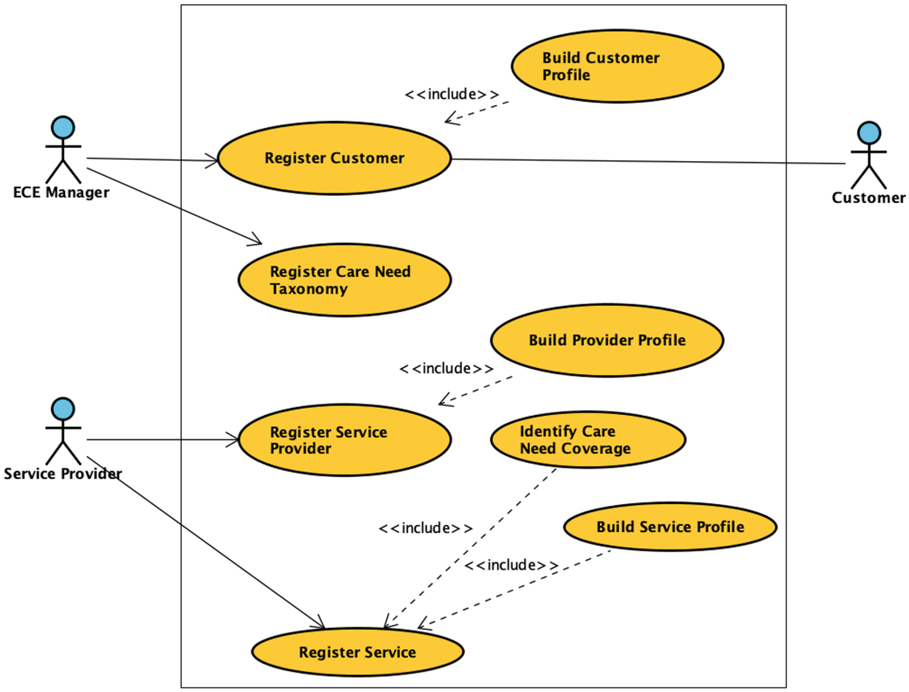

Fig. 4. ECE preparation phase use case diagram

The taxonomy (TX) is registered by the ECE Manager (*Register Care Need Taxonomy*). Only one instance of the taxonomy exists for each ECE. The taxonomy evolves over time and new nodes can be added, updated or deleted. The customer (*Register Customer*), service provider (*Register Service Provider*), and service profile (*Register Service*) are registered through predefined templates. More details about these ECE profile templates can be seen in [6].

4.2 Execution Phase: Customer Request and SCoPE Algorithm Execution

The ECE execution phase covers the following main activities: Customer request, and SCoPE algorithm execution. Figure 5 presents a partial use case diagram of this phase. The ECE Manager selects the customer (*Select Customer*) and registers her/his request (*Register Customer Request*). The personalization algorithm (SCoPE) is executed (*Execute Personalization Algorithm*) by the *Solution Processor* and a list of solutions are presented to the customer (*List Solution*). The customer chooses the best solution for her/him (*Solution Validation*).

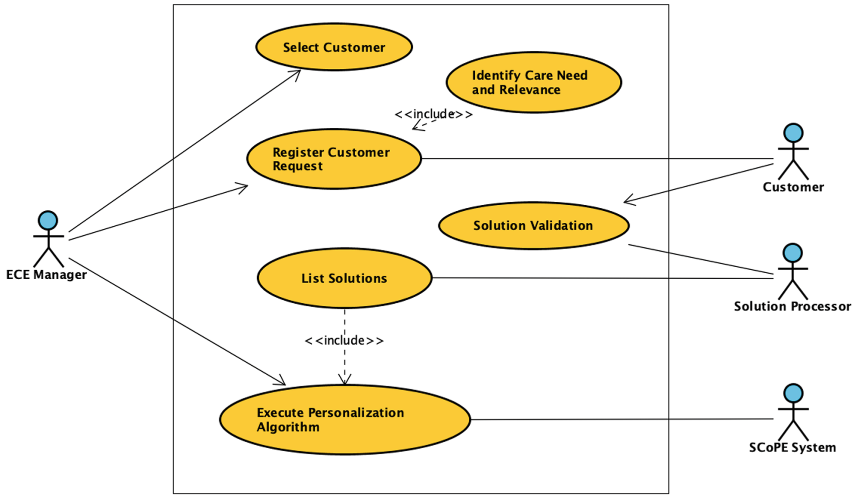

Fig. 5. Customer request and algorithm execution use case diagram

An example of customer profile and request is shown in Fig. 6, where the customer *Beth Maria Santos* is inserted in the ECE with her personal data, limitations and resources, and life style characteristics (part of ECE customer profile template).

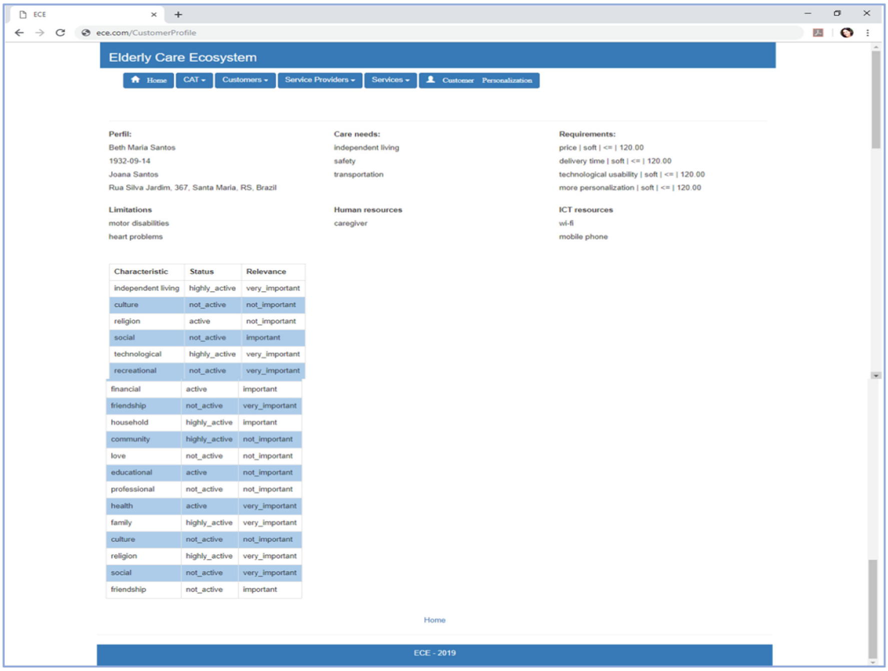

Fig. 6. Customer's profile and request presentation in the ECE software prototype

4.3 Monitoring Phase: SEvol Algorithm Execution

The ECE monitoring phase covers the following main activities (see Fig. 7): *Receive Inputs* including update of customer request (*Customer Request Update*), *Evolution Algorithm Execution* (SEvol), resulting in the new solution (*Evolutionary Solution*), and validation of the evolved solution by the customer (*Solution Validation*).

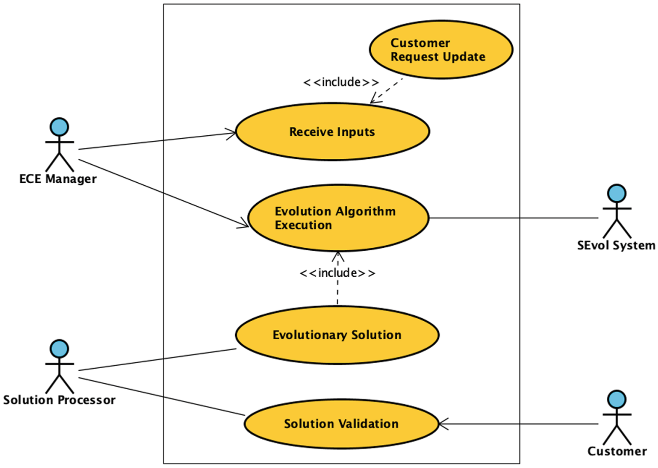

Fig. 7. Monitoring phase partial use case diagram

The partial steps of service evolution as implemented in the software prototype are presented in Fig. 8. In this example, the care need *independent living* is removed and the new care need *recreational activities* is added with *high* relevance. The evolution algorithm is executed, and the solution is presented for customer validation. More details about SEvol algorithm execution can be seen in [9] and [10].

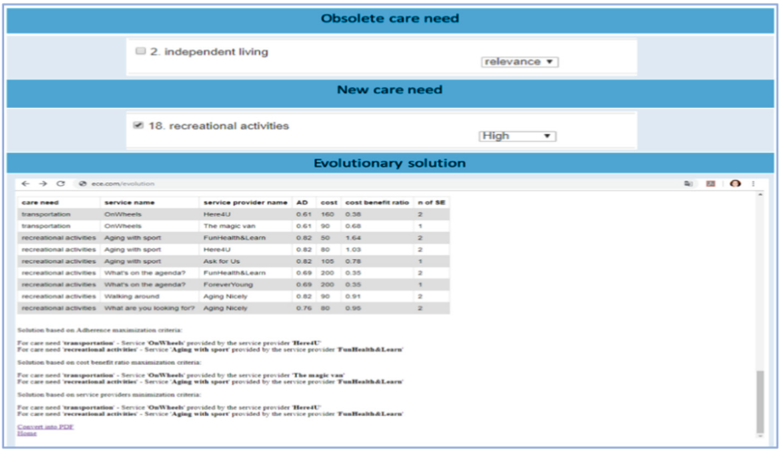

Fig. 8. Evolutionary solution partial steps (in the software prototype)

5 ECE Framework Evaluation

The statements presented in the survey belong to eight dimensions (four originating from TAM and four created for our work) organized in three contexts (built for our evaluation area) that we want to assess: technological context, organization context, and collaborative environment context. Figure 9 shows the proposed model with the corresponding contexts and dimensions.

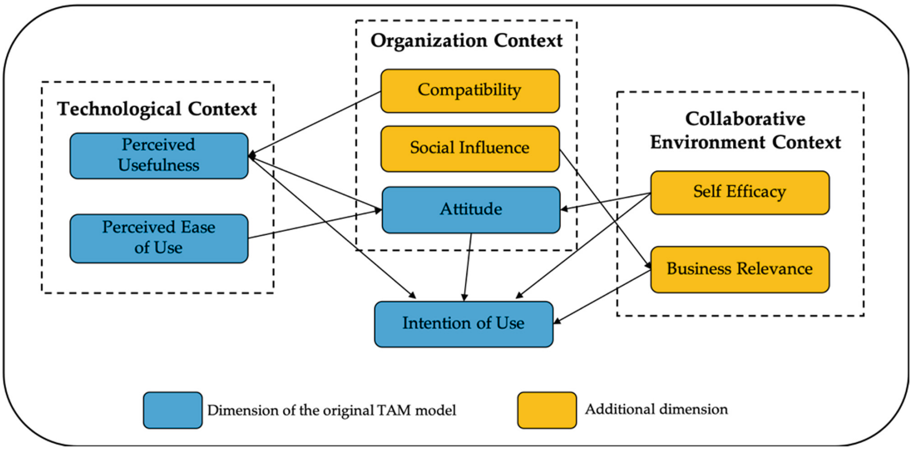

Fig. 9. Extended TAM model

The *Technological Context* includes the dimension *Perceived Usefulness* and *Perceived Ease of Use* from the TAM methodology. The *Organizational Context*, encompasses the dimensions *Attitude*, *Compatibility*, and *Social Influence*. *Attitude* can be defined as the perception by an individual of the positive or negative consequences related to adopting the technology. *Compatibility* refers to the degree of correspondence between an innovation and existing values, past experiences, and needs of potential adopters. *Social Influence* assesses the extent to which an individual believes that stakeholders who are important to him/her will approve his/her adoption of a particular behaviour.

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

Four items about each variable dimension are collected in the survey, totalling thirty-two items. The questions belonging to the various dimensions appear mixed to mitigate any bias in the responses.

Considering the elderly care domain and its business environment, a set of service providers and experts of different type of business are identified: public, philanthropic, private, and mixed organizations. All selected organizations operate in Brazil, at different levels with local, regional, and national market influence.

5.1 Survey Application and Results Analysis

The questionnaire was tested with 95 elderly care professionals belonging to 17 distinct companies. Respondents answered the questionnaire by rating each item on a 5-point Likert scale [11] ranging from “totally disagree” to “totally agree.” Scores were developed by computing the mean of all the items that constitute each dimension. Additionally, respondents had to provide information about their age, gender, nationality, background area, number of years in the company, experience in the elderly care domain and in the collaborative networks, and the highest educational grade obtained.

The internal consistency of the instrument was assessed by calculating the Cronbach alpha [12] values for each variable. The construct validity of the model was evaluated using interitem correlation analysis. Cronbach alpha values were acceptably high (>0.7 by [13]) for the remaining theoretical constructs (see Table 1).

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

Table 1. Sample item and Cronbach α by dimensions (translated to English)

Dimension	Sample item	Cronbach α
D1: Perceived Usefulness	ECE can facilitate the service personalization and evolution to my customers	0.81
D2: Perceived Ease of Use	I think that I could easily learn how to use the ECE	0.79
D3: Compatibility	The customer data profile used by ECE is appropriated to my business strategy	0.75
D4: Social Influence	Most of my customer will welcome the fact that I use the ECE	0.82
D5: Attitude	In my opinion, the use of ECE' profiles (service, service provider, customer, and care need) will have a positive impact for service provision	0.81
D6: Self Efficacy*	I would use ECE if I receive appropriate training and the necessary technical assistance	0.78*
D7: Business Relevance*	I believe that the ECE represents a competitive advantage in a fierce market	0.82*
D8: Intention of Use	I intend to use the ECE in my organization when it becomes available	0.90

*considered only for those who work with collaborative networks.

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

The results of items and related dimensions are summarized in Fig. 10.

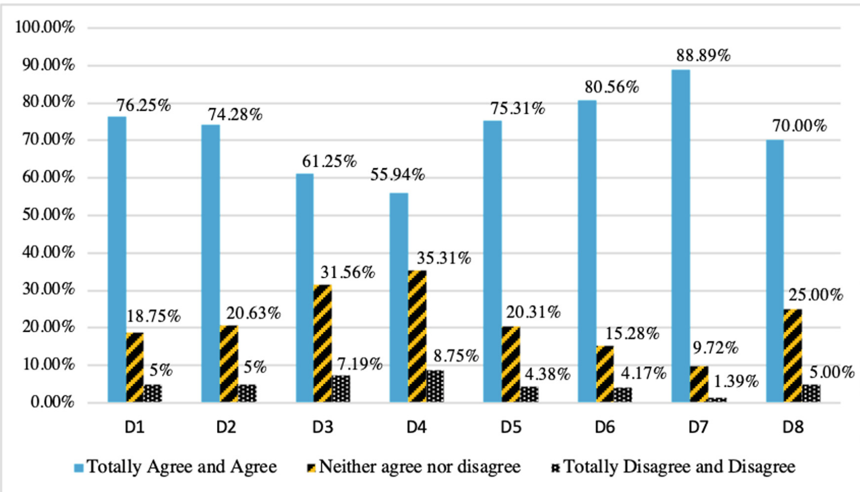

Fig. 10. Summary of results and related dimension

In general, all dimensions had a high acceptance. The two dimensions that were below 70% were D3 and D4. In both, there is a high index of neither disagreement nor agreement. In *Compatibility*, an identified outline refers the absence of the use of an ecosystem to service personalization and evolution (none of the companies we visited has a system for recommendation service; this task is still a human decision).

Relating to *Social Influence,* the participants believe that the customers may not accept being monitored for fear of losing their privacy, and the ECE members may not provide complete data because they feel unsafe and fear disclosure of sensitive information to their competitors (now partners in ECE). With the large data handled by ECE, a reliable information security policy should be implemented to manage the uncertainties which might affect the security of their organization´s information over time, and privacy namely in accordance to GDPR rules. It is demanding proper investment and business adaptation for participating of the ECE.

5.2 Study Limitations

The results of our study should be interpreted in the light of some limitations. First, the same questionnaire was used for staff, caregivers and managers. If we did one for each type of entity, we might get more real data per actuation area. Second, we identified that the concept of collaborative networks is often confused with "cooperatives" in Brazil. Thus, we are not sure that the participants who stated that they work with collaborative networks really do, since they also do not have a computer-based collaboration system. Considering that the dimensions *Self-Efficacy* and Business *Relevance* were evaluated by workers in collaborative environments, the results may not reliably reflect the reality.

A third aspect to consider is that our theoretical model involves additional constructs in relation to the original TAM methodology. It would be interesting to test this model in a future work and add other potentially important variables to improve the predictive power of the theoretical model. Finally, the technology may be a barrier to understanding the proposed concept because most caregivers do not use technologies to provide a service.

6 Conclusions and Future Work

In this paper, we presented an overview and a prototype of an Elderly Care Ecosystem. The main focus of this work contemplates the ECE software prototype implementation and the ECE conceptual framework evaluation based on a survey following a modified TAM. The prototype is presented based on the main functions and steps to algorithm execution. With the demonstration and survey application, the ECE utility and applicability test with partners and related stakeholders (caregivers and elderly care enterprises) is done. The results analysis is presented and in general, all dimensions had a high acceptance. Moreover, the current understanding of the links among collaborative networks, care ecosystems, and personalized and evolutionary services provision, is new and not fully consolidated, representing a challenge.

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