Open Innovation in Health Service Value Networks: A Methodology for the Innovation of Ambient Assisted Living Platforms and Services

Davor Meersman[1] and Pieter De Leenheer[2]

[1] Curtin University
Kent Street, Bentley 6102, Australia
d.meersman@curtin.edu.au
[2] VU University Amsterdam
De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands
p.g.m.de.leenheer@vu.nl

Abstract. In this paper we introduce a methodology for collaborative innovation in the ambient assisted living domain using service value networks. We look to solve problems associated with heterogeneity, domain knowledge formalisation, low acceptance, integration and immaturity in the ambient assisted living domain. Our methodology consists of domain elicitation and modelling, needs elicitation and laddering, atomisation, recombination, and deployment and monitoring.

Keywords: ambient assisted living, healthcare systems, innovation, service value networks, service platforms.

1 Introduction and Motivation

The population of the European Union is undergoing significant demographic changes that have various implications on the nature of services and innovations in the current and future extended European economic space. By 2060, the European population older than 65 years old is projected to be more than 30 percent [1]. The associated cost of consequentially increased care is expected to be a significant burden on European economies [2]. This effect is further exacerbated by the old age dependency ratio (i.e. the population older than 65 divided by the working age population supporting them) is expected to rise from 25% to 53% by 2060 [1], meaning that for every old person there will be maximally two people of working age that can support that person, compared to four people now.

Assisted living solutions underpinned by ambient intelligence technology have been identified as a viable option to mitigate the impact of the associated cost of the demographic changes faced by Europe. This trend is apparent also from the European Commission's comprehensive Ambient Assisted Living (AAL) Joint Programme, which has funded 50 projects to date with a budget of EUR 600 million in calls focusing on the prevention and management of chronic conditions, the advancement of social interaction, and on the advancement of elderly people's independence and

W. Abramowicz, J. Domingue, K. Węcel (Eds.): BIS 2012 Workshops, LNBIP 127, pp. 25–36, 2012.

participation in the ‘self-serve society’ [3]. AAL technologies can help provide autonomy to elderly and disabled people, allow them to live at home individually for longer, raise their quality of life and to relieve some of the economic burden on public health care systems in the process.

The content of this paper is organised as follows: Section 2 discusses the home care systems and AAL technologies. Section 3 outlines the challenges in AAL. Section 4 discusses innovation in the context of healthcare platforms and services. Section 5 introduces Service Value Networks as a vehicle for collective intelligence and co-creation. Section 6 outlines the innovation methodology, including elicitation and modelling, atomisation, recombination, and deployment. Section 7 evaluates the methodology in light of the AAL challenges. Section 8, finally, draws some conclusions and projects future work.

2 Home Care Systems and AAL

Systems focusing on supporting people with special needs in their home environment are called Home Care Systems (HCS). Technologies underpinning home care have various labels. ‘Assisted Living’ refers to devices and services that help people stay at home longer. ‘Assistive Technologies’ refer to devices that aid with daily living of patients. ‘Telehealth’ and ‘Telecare’ refer to remotely monitoring and supporting patients. ‘Smart Home‘ refers to home automation and monitoring via sensor networks [4]. The home care system domain is coarsely categorised in [2] as follows:

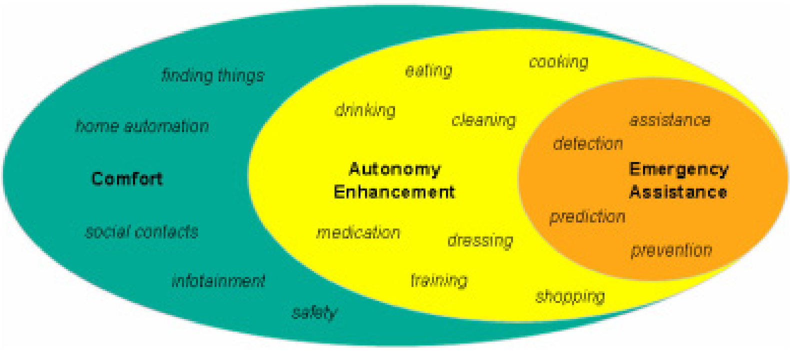

Fig. 1. The home care system domain [2]

What are defined in Fig. 1 as comfort, autonomy enhancement and emergency assistance services, can be seen as a rudimentary categorisation of patient needs, serviced by service providers. In our methodology, we use laddering techniques to derive specific needs from these general patient needs (described in Section 6). In the HCS domain, there are 2 main actors: Service Recipients (patients) and Service Providers (including physicians, home care givers and relatives) [5].

For now it is important to note that whilst the above categorisation is useful in itself as a description of the domain, it has no real function in the context of developing innovative home care services. Innovators in the domain are generally already well endowed with the intricacies of the domain, and a categorisation has the limitations that processes belong to a single category. For instance, in the context of remote Diabetes Type 2 monitoring and management, the process `Medication` might satisfy the `EmergencyAssistance` need via a `ContinuousGlucoseMonitoringSystem` administering `Insulin` to the `Patient`, rather than satisfying `AutonomyEnhancement` as is proposed in the model.

Today's commercially available technologies in the AAL domain are products such as necklaces with emergency buttons, fall sensors in mobile phones with notification services, vital data monitoring plasters, wireless blood pressure and blood glucose meters [2, 5], and a myriad of other technologies that are increasingly being integrated in a smart object-based Internet Of Things with corresponding wireless standards such as ZigBee Pro [6] and 6LoWPAN [7].

3 Challenges in AAL

The ambient assisted living domain is relatively young and in the early stages of its development. A number of technological AAL challenges have been identified in [2]:

1. Adaptivity: systems need to monitor their environment and adapt themselves constantly.
2. Natural interactions: systems need to provide interfaces for users with varying needs.
3. Heterogeneity: systems are closed, standalone, and provided by different suppliers with diverging knowledge and technologies.
4. Domain knowledge formalisation: domain knowledge that is difficult to formalise needs to be transformed for processing.
5. Elderly stakeholders: the main stakeholders of AAL have generally low degrees of computer literacy and variable degrees of mental clarity, alertness and memory function, creating interface constraints.
6. Low acceptance: systems that are marketed as solely assisting with health problems have low acceptance rates because of the social stigma associated with them.
7. Integration of available technologies: AAL systems and services are characterised by heterogeneity, which offers integration challenges.
8. Immaturity: although it is generally expected that AAL will be a huge market, there is only limited knowledge about what the products will look like, what their economic viability will be, who will provide them, how they will integrate, etc.

In our work we focus on tackling 5 out of 8 of the above challenges for the AAL domain, namely we look to solve problems associated with *heterogeneity, domain* *knowledge formalisation, low acceptance, integration* and *immaturity*. This is done in collaboration with a large telecommunications provider who provides the supporting smart home communication infrastructure on top of which the AAL devices and services exist. The smart home platform hardware consists of a back-end and network infrastructure, and a home gateway that controls a wireless sensor network, network communications and the delivery of a range of services including but not limited to: health, security and smart energy. The provision of services of these three domains over congruent endpoint infrastructure reveals that many services are overlapping and there is no need for disjoint approaches that result in a proliferation of heterogeneous systems and services that are potentially not economically viable or interesting on their own (e.g. solutions in the long tail of the spectrum). As a result of the agnostic product atomisation process in our methodology, different service providers can (collaboratively) innovate in adjacent domains. This blurs unnecessary, conceptual and artificial boundaries between domains.

4 Healthcare Platform and Service Innovation

There are two dimensions to the pace and nature of innovation on a HCS platform. One dimension is the evolution of the platform itself. As the platform grows and transforms, new capabilities are added to support new types of services. The other dimension is the innovation of services. By identifying, composing and developing new services, emerging customer needs are to be met with current platform capabilities. The platform innovation life cycle is typically slower because it involves hardware engineering, high investment costs and the need for a relatively stable service environment, whereas service innovation has a more dynamic nature and can thus respond to emerging customer needs faster [8]. However, all services are dependent on the platform over which they are delivered. Consider, e.g., the release of the iPhone 4 platform, which through its new 3-axis gyroscope functionality allowed the iPhone developer network to build new 3-axis gyroscope-utilising services that had heretofore not been possible. Or closer to home in the HCS domain, e.g. the introduction of fall detection sensors has enabled service providers to deliver emergency assistance to patients. Therefore innovation in a service-based economy will have a dual character of platform and service innovation, with the platform determining the provided services, and the services (or lack thereof) influencing the shaping of the platform.

A platform provider needs to take into account service dynamics and the evolving technological landscape, and anticipate accordingly. Related work on health care service customisation and personalisation [9, 10] is valuable and useful, but does not generally include platform constraints and evolution when devising new services. For this reason, whilst new services do arise from personalisation and customisation, it cannot be fully considered service innovation.

5 Use of Service Value Networks as Collective Intelligence for Service and Platform Innovation

The potential range of services in the HCS domain is huge. This has led to a proliferation, making it difficult to innovate in the space as such. Each provider supplies part of the solution, but suppliers do not co-innovate systematically. In our approach, we use Service Value Networks (SVN) as an ecosystem for collective intelligence, co-creation and open innovation. A service value network is a flexible and dynamic web of enterprises and final customers who reciprocally establish relationships with each other for delivering an added-value service to a final customer (see Razo-Zapata et al. [11]; Hamilton [12]; Allee [13]; and Lovelock and Wirtz [14].

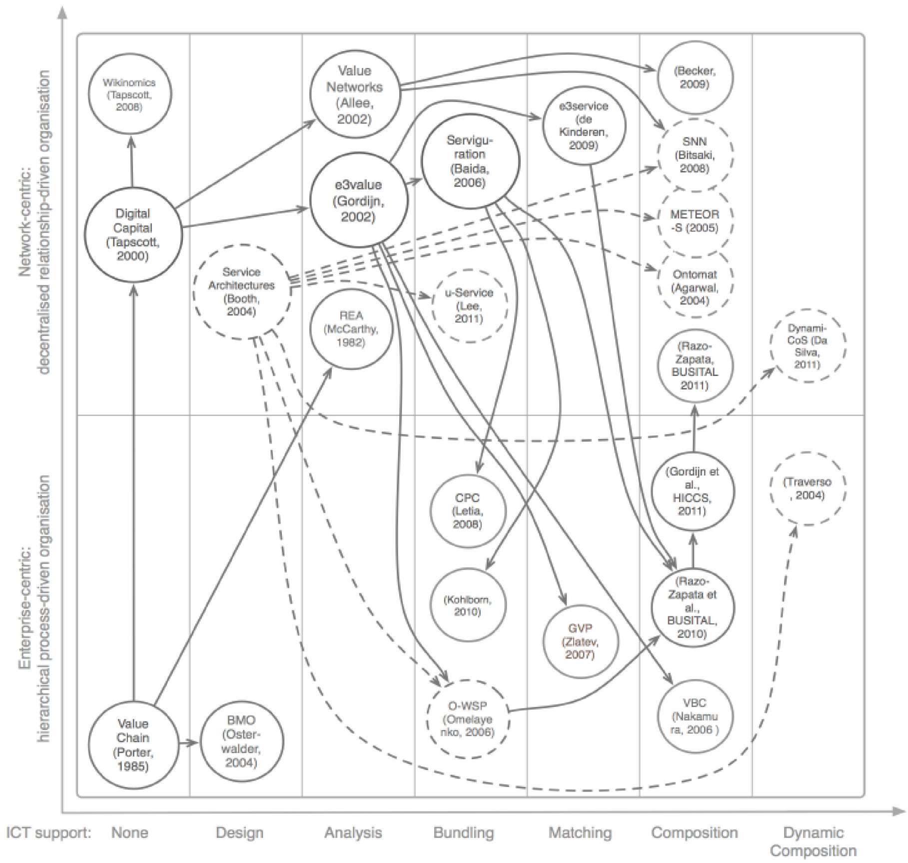

Fig. 2. Service Value Network approaches [11]

Whereas Value chains were sequences of activities that add each value to a production process, in SVNs the value is co-created in a networked setting. The key issue of SVN technology research is to automatically match customers with competencies on the market. In other words, SVN composition aims to bundle relevant competences in a network such that they deliver value in such a way that they answer a customer need. Suppliers, as well as customers can deliver these competencies. This value co-creation happens usually in different tiers: at B2C side, service providers make sure they offer relevant competences in fulfilment of a customer need; at B2B side service enablers make sure the technology space can make these services possible [15].

The foundation for SVN that is adopted in our approach is the well-established e3value [16, 17]. It provides ontologies to analyse and model perspectives of customers and providers on service needs. Inspired by service marketing and management theory, the conceptualisation of services focuses on value aspects, rather than merely computer-technical aspects as found in most service-oriented computing paradigms. As depicted in Fig. 2, e3value has been evolving since 2002 taking up different related service network approaches.

It shows how the innovation space in which different SVN approaches have emerged from business research [18, 19] and influenced each other. Solid circles represent business-oriented approaches taking into account value aspects of services, whereas dotted circles stand for process-oriented approaches hence focusing more on software aspects of services. The axes of the space indicate how these approaches co-evolve with changing business practice trends and increasing demand for ICT support: vertically, there is the economic context, which is evolving from a hierarchical process-driven organisation to a decentralised and relationship- driven organisation. Horizontally, there is the support of ICT in the different activities of SNs in these organisations.

The direction in which we aim to advance current state of the art lies in dynamic composition of service value networks in decentralised business environments. This corresponds to the upper-right corner of the SVN innovation space in the figure. These trends are confirmed in business research literature by, i.a., Tapscott [20], Van Heck and Vervest [21], and Chesbrough [22].

6 Methodology

Domain Elicitation and Modelling

The initial step is the analysis of industry-sourced information provided by industry representatives. This encompasses manuals, design documents, project deliverables, personas, training manuals, expert interviews, etc. Based on the initial domain knowledge, we develop a high-level domain model with a low granularity. After breaking up the domain in these main building blocks, we add general concepts and relations without delving into the specifics too much.

Adhesive	is a	subsumes	Property
Bathing	is a	subsumes	Process
AutonomyEnhancement	providedby	provides	Training
Infotainment	is a	subsumes	Process
AutonomyEnhancement	providedby	provides	Medication
ServiceProvider	performs	isperformedby	Process
Process	is a	subsumes	T
GlucoseSensor	usedin	uses	Prevention
Comfort	providedby	provides	SocialContacts
Actor	is a	subsumes	T
EmergencyAssistance	providedby	provides	Detection
ContinuousGlucoseMonitoringSystem	haspart	partof	Transmitter
Drinking	is a	subsumes	Process
Needs	is a	subsumes	Quality
AutonomyEnhancement	providedby	provides	Drinking
EmergencyAssistance	providedby	provides	Assistance
Sensor	is a	subsumes	Object

Fig. 3. Examples of lexons

In the domain modelling phase, we formalise the interview annotations as lexons (see Fig. 3), according to the DOGMA approach. A lexon represents a binary fact-type and is formally described as a 5-tuple (γ , concept A, role, co –role, concept B) where γ is the context (γ not shown in Fig. 3) [23]. The context is the HCS domain in our case. Role and co-role represent the relation and inverse relation of the respective concepts. The facts are added to the ontology until the representation for that part is complete, based on the provided information. Assumptions from the initial ontology are trumped by domain expert evaluations.

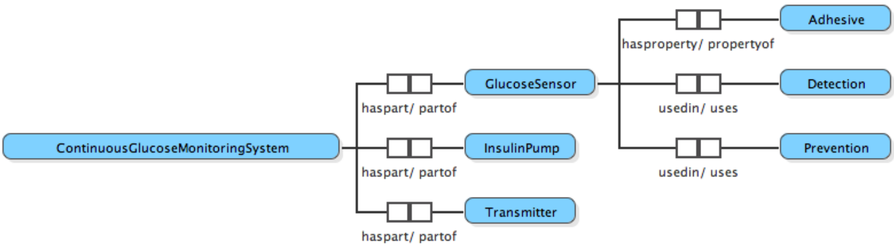

Fig. 4. Example of a domain knowledge pattern

Subsumption relations are modelled separately from other relations. The highest level of the subsumption hierarchy features the following classes [24]:

- Actor: any actor using objects in any process in the domain
- Object: products and components used in processes by actors and objects

- Process: any process in the domain, executed by an actor with the use of objects
- Quality: concepts that define how, to what extent, when etc. something happens; properties and functions of objects, actors and processes. The product application context is also included in the model, as the function of the product has an influence on the reasoning behind feature introduction. By formalising the entire domain, one can for example gain valuable insight in how certain functions that are performed by users today can be taken over by technology tomorrow.

Needs Elicitation and Laddering

Laddering has been widely used in marketing to represent how customers link specific product properties to high-level values [25]. In our case, by making use of the domain model, patient needs as stated by the domain model are refined into so-called functional consequences or FCs. For instance, a patient need such as “As an elderly diabetic, how can I enhance my autonomy?" can be refined into the following FCs: `Assistance`, `Prediction`, `Prevention`, and `Detection`. These processes use the following objects in the context of diabetes: `ContinuousGlucoseMonitoringSystem`, `BloodGlucoseMonitor`, and `InsulinPump`. These processes and objects better describe a patient need in terms of specific requirements [25, 26, 27].

Atomisation

We extract abstract properties and functions from objects, services and components in a domain. Properties and functions are related and one can rebuild objects and services based on their properties and functions.

Because the existence of properties in a domain is driven by the function they perform, i.e. the fulfilment of initial requirements and in some cases posterior cost considerations, the inclusion of functions and their linkage to products, product components and product properties is crucial in the context of ideation. Why is something there?

Recombination

Based on previous work on ‘directed variation’ [28] focusing primarily on product engineering, we recombine property/function clusters to create new services or products (i.e. platform components in the case of the HCS domain) based on elicited user needs. Product/service innovation takes places when a new property is found for an existing function, or when a new function is found for an existing property (see Fig. 5). Common examples of this principle in innovation are the Swiffer, the billion dollar brand household cleaner (property ‘static electricity’ instead of ‘suction’ for function ‘cleaning’) [28], or Jack Daniels Smoking Pellets, composed out of chopped up whiskey barrels (function ‘burning’ instead of ‘containing’ for wooden barrel properties).

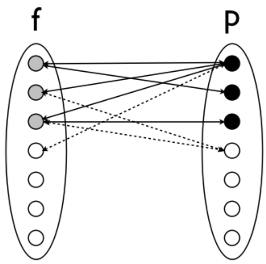

Fig. 5. Schematic representation of the recombination of properties p and functions f

In the HCS domain, patient needs are linked to property/function clusters. Processes (laddered needs) are linked to objects (property/function clusters). When new needs arise, the SVN evaluates them in terms of how they are linked to their part of the property/function cluster. It is important to identify a candidate service space that can fulfil the anticipated needs. For example, `Detection` and `Prevention` are linked to `FallDetection + Seismometer` and its properties. By recombining the properties, a certain type of `Accelerometer` can be a better solution for certain processes (for example in case of absence of possibility of seismometers, or when their properties cannot perform their function). By the principles of atomisation, the SVN can agnostically design solutions, and even providers outside of the traditional HCS scope can offer contributions.

Deployment

SVN design results in a set of quasi-equally interesting compositions of products/services that answer to the valued requirements. We verify their market suitability and derive a ranking by deploying them for limited and separate audiences. We then deploy the best-scoring SVN designs in a commercial setting and monitor/adapt them. This makes sure the innovation is sustaining under potentially disruptive technical innovations, and anticipates and co-evolves with changing business needs and technical opportunities.

7 Evaluation

Our approach for innovation in the HCS domain focuses on tackling following challenges for the AAL domain: heterogeneity, domain knowledge formalisation, low acceptance, integration and immaturity.

The use and SVNs in innovation promises to alleviate some of the burdens associated with heterogeneity: by collaboratively innovating across company boundaries, domain limits, and service/platform divisions.

Our approach of combined high-level domain formalisation and agnostic atomisation offers opportunities for domain formalisation in an innovation context. We do recognise that in the context of medical services and science, the intricacies of the domain remain.

The agnostic nature of the atomisation process and the trans-domain context of our industry smart home use case (health, security, energy) offers opportunities for breaking open a perhaps currently too narrowly defined HCS domain.

By having a single, standards-compliant platform provider, integrated component providers and a service provider network, some of the integration challenges are solved at the requirements and subsequent innovation stage.

Finally, perhaps a generalised domain model with extractable function/property clusters and laddered customer needs, can shed light on the reality of the HCS domain.

8 Future Outlook and Conclusions

In future research, we will start using sensor data in our innovation process. The data-heavy nature of the sensor-driven AAL domain will provide opportunities for detecting and eliciting emerging patient needs patterns use these in innovation processes.

The smart home context of our AAL industry use case will allow service value networks from various domains to contribute to a more integrated view of AAL of which the boundaries blur into other domains.

Another area of research is the distinction between services and platform in light of atomisation, and how we can interpret new or unmet emerging service needs as patterns for platform innovation.

A final aspect for future work is the evaluation of the methodology by examing the process outcomes: during deployment, the innovation is deployed and its success measured, which also determines the success of the current methodology.

The principles and methodology introduced in this paper provide a novel framework for innovation in the ambient assisted living domain. Specifically, they contribute solutions to the problem scope of heterogeneity, domain knowledge formalisation, low acceptance, integration, and immaturity of AAL through domain elicitation and modelling, needs elicitation and laddering, atomisation, recombination, and deployment and monitoring.

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