A New Living Lab for Usability Evaluation of ICT and Next Generation Networks for Elderly@Home

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Abstract. Living Usability Lab for Next Generation Networks (www.livinglab.pt) is a Portuguese industry-academia collaborative R&D project, active in the field of live usability testing, focusing on the development of technologies and services to support healthy, productive and active citizens. The project adopts the principles of universal design and natural user interfaces (speech, gesture) making use of the benefits of next generation networks and distributed computing. Therefore, it will have impact on the general population, including the elderly and citizens with permanent or situational special needs. This paper presents project motivations, conceptual model, architecture and work in progress.

1 Motivations for a New Living Lab

The importance of communication and information technologies in today's society is universally recognized. New services introduced radical changes in our lives and increased considerably the spectrum of end-users. On the other hand, the proliferation of multiple platforms and interaction infrastructures may create serious problems of access to the diversity of information services currently available. This is a serious problem of social exclusion.

From the need to overcome the gap between an individual's capabilities and the technological resources originates the term accessibility, meaning access to equipment and services, in terms of quantities, appropriate locations and convenient

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operating times and adequacy of the hardware and software to any user. It is a complex concept because it involves many dimensions.

1.1 The Usability and User Acceptance Challenge

Usability is a term used to denote the ease with which people can employ a particular tool or other human-made object in order to achieve a particular goal. Usability can also refer to the methods of measuring usability and the study of the principles behind an object's perceived efficiency or elegance [1]. In human-computer interaction and computer science, usability often refers to the elegance and clarity with which the interaction with information system is designed.

User acceptance differs from usability insofar as the first also embraces usefulness. Use and acceptance of technologies and technical devices depend on various factors such as adequate design, financial resources, housing situation, which functions shall be compensated or strengthened by technologies and which skills and competences still exist.

1.2 From Next Generation Networks to New Services

Next Generation Networks (NGN) are defined by the International Telecommunication Union (ITU) as a “packet based network able to provide services including telecommunication services and able to make use of multiple broadband, QoS-enabled transport technologies and in which service related functions are independent from underlying transport-related technologies”. NGN offer access by users to different service providers and supports “generalized mobility which will allow consistent and ubiquitous provision of services to users” [2].

NGN include next generation “core” networks, which evolve towards a converged IP infrastructure capable of carrying a multitude of services, such as voice, video and data services, and next generation “access” networks, i.e. the development of high-speed local loop networks that will ensure the delivery of innovative services.

The investment in developing NGN is motivated by several factors [3], including social motivations, such as the demand for more personalized content or the demand for increased interactivity.

Web 2.0 technologies combine two important characteristics or features: collaboration and interaction. By collaboration, we refer to the “social” aspects that allow a vast number of people to collaborate and share the same services, applications and data over the Web. An equally important aspect of Web 2.0 technologies is interaction. Web 2.0 technologies make it possible to build web sites that behave much like desktop applications, for example, by allowing web pages to be updated one user interface element at a time, rather than requiring the entire page to be updated each time something changes.

This particular trend has made popular certain technologies like Web Services, Mashups and software architectures like Service Oriented Architectures (SOA) or Cloud Computing.

1.3 The Living Lab Concept

A challenge for information and communication technology (ICT) providers is to involve users in the innovation process, from the early phases of context research and idea generation through the later phases of development and implementation. Important issues include access to adequate knowledge regarding the user context, early validations in the market, trials in contexts familiar to users, valid user feedback on state-of-the-art ICT solutions and utilization of users as a co-creating resource [4].

Living Labs are environments for innovation and development where users are exposed to new solutions in (semi)realistic contexts, as part of medium or long-term studies targeting the discovery of innovation opportunities [4].

The Living Lab is a new research paradigm (more than an experimental facility as its philosophy is to turn users and intends to: increase the understanding of occurring phenomena; explore and evaluate new ideas, concepts and related ICT artefacts; confront new ideas, concepts and related ICT artefacts with users' value model; enable re-usable experiments; result in more accurate and reliable products and services; speed-up concepts to market and promote vital adoption; contribute to initiate potential lead markets; contribute to bring science and innovation closer to the citizen.

The Living Lab methodology comprises several phases [5]:

– Generating insights – Living Lab provides access to large numbers of users, generating insights into living behavior. Data is recorded via user-reporting and non-obtrusive observational techniques;

– Developing and experiencing insights generated in the field are translated into sustainable solutions by multi-disciplinary teams. Early prototypes are installed in the Living Lab and tested by real users;

– Evaluating prototypes - fully functional prototypes are installed in existing or newly built physical spaces in order to let users experience future product and service ideas.

2 Project Scenario - Active Ageing at Home

According to the World Health Organization (WHO), population ageing is one of humanity's greatest triumphs. It is also one of our greatest challenges: the global ageing will put increased economic and social demands on all countries. At the same time, older people are a precious, often ignored resource that makes an important contribution to the fabric of our societies [6].

The WHO argues that countries can afford to get old if governments, international organizations and civil society enact active ageing policies and programmes.

The word active refers to continuing participation in social, economic, cultural, spiritual and civic affairs, not just the ability to be physically active or to participate in the labour force [6]. Considering the WHO definitions, active ageing [6]:

– Is an approach based on the recognition of the human rights of older people and the United Nations (UN) principles of independence, participation, dignity, care and self-fulfilment;

– Is the process of optimizing opportunities for health, participation and security in

order to enhance quality of life as people age;

– Refers to continuing participation in social, economic, cultural, spiritual and civic affairs, not just the ability to be physically active or to participate in the labour force;

– Allows people to realize their potential for physical, social, and mental well-being throughout the life course and to participate in society, while providing them with adequate protection, security and care when they need;

– Shifts strategic planning away from a needs-based approach (which assumes that older people are passive targets) to a rights-based approach that recognizes the rights of people to equality of opportunity and treatment in all aspects of life as they grow older;

– Considers that older adults maintaining autonomy and independence are key goals in the policy framework.

The adoption of healthy lifestyles and actively participating in one's own care are important at all stages of the life course. One of the myths of ageing is that it is too late to adopt such lifestyles in the later years. On the contrary, engaging in appropriate physical activity, healthy eating, not smoking and using alcohol and medications wisely in older age can prevent disease and functional decline, extend longevity and enhance one's quality of life. Opportunities for education and lifelong learning, peace, and protection from violence and abuse are key factors in the social environment that enhance health, participation and security as people age. Loneliness, social isolation, illiteracy and a lack of education, abuse and exposure to conflict situations greatly increase older people's risks for disabilities and early death.

The capacity of an older person to continue to work in a paid or voluntary capacity is emphasise by the concept of productive ageing [7].

ICT have an important role within the active and productive ageing, whether they are used to extend the life span, to promote the activity and participation of older adults, to reorganize the health and social support services or simply to disseminate information. With suitable natural interfaces and the possibilities offered by next generation networks, the introduction of technological solutions can facilitate the daily life of the elderly, fighting isolation and exclusion, increasing their pro-activity, work capacity and autonomy. The envisaged services are: multimedia information access and exchange of personal data; telehealth and automatic medication delivery; support of daily activities and community, social and civic life; and automatic management of the environment to improve both the quality of life and security.

2.1 Elderly at Home

Whatever forms of support (at home or some institution), the elder is a person with multiple needs demanding support from multiple health and social services. The development of information services for such a scenario requires a diverse set of users (elderly, family, informal and formal caregivers), very different tasks and different contexts of use.

In supporting the elderly, particularly in home care, many tasks require human contact. However, with adequate interfaces, the introduction of technological solutions can have much impact, namely in:

1. Daily Life: Help with activities of self care, support in carrying out domestic acti-

vities, environmental monitoring and home automation (e.g. lights control);

2. Personal Development: To support the development of learning activities throughout life, recreation and other community activities;

3. Development of specific programs of rehabilitation and health education;

4. Medication: Notification and dispensing of medication;

5. Monitoring state of health: Vital signs (e.g. blood pressure and heartbeat frequency), nutrition and mental functions;

6. Personal Security: Notification in situations of falling and change of routines (e.g. motionless for a long time);

7. Home security, including intrusion and fire alarms.

3 Living Usability Lab Overview

The project aims to create a technology platform enabling development, integration and evaluation of applications and services to optimise universal accessibility applicable, inter alia, to the case of the elderly population, using NGNs.

For this access for all to become possible is necessary to investigate, develop, integrate, assess and better understand the integration technologies, contemplating since the interface device level (ex: voice capture) to the knowledge management system and complex services.

3.1 Conceptual Model

By definition, a Living Lab is not just a set of information services, but a complex entity, composed by physical spaces and infrastructures (information and communication systems and services, peripheral devices, development tools and methodologies for analysis, specification, evaluation, validation and dissemination of the results) requiring intense involvement of stakeholders (for instance, end users, professionals, researchers or students) to allow the research and development, in continuum, of new technologies and services. This can be viewed (Fig. 1) as a stack of the layers: (1) Physical Spaces, (2) Physical Infrastructure, (3) Logical Infrastructure, (4) Development Platform, (5) Methodologies, (6) Applications, and (7) Stakeholders.

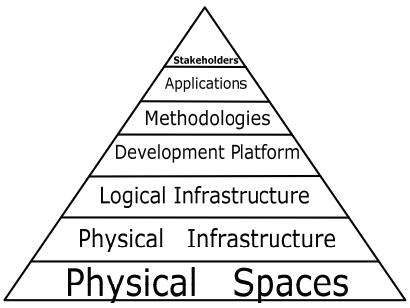

Fig. 1. Living Lab Conceptual Model.

3.2 Physical Spaces

Living Lab concept is a challenge to involve users in the innovation process, from the early phases of context research and idea generation through the later phases of development and implementation. For that, the Living Lab should have conditions in order to expose users to new solutions in (semi)realistic contexts. In order to involve older adults in realistic scenarios several physics spaces will be included:

- A Laboratory of Gerontology (small apartment used for teaching at University of Aveiro Health School);
- A Family House (integrated in a Rehabilitation Center);
- Apartment(s).

It is essential that researchers and students for Health courses be also involved in the Living Lab. Therefore, besides the Laboratory of Gerontology, Living Lab will also include a research lab (at the Institute of Electronic Engineering and Telematics of Aveiro) and at MLDC (Microsoft Language Development Center in Porto Salvo).

Service providers have a key role for a Living Lab, up to the point that sometimes the service provider is taken as synonym for the Living Lab. Therefore, a social institution providing care to older adults (Santa Casa da Misericórdia de Oliveira do Bairro) and a rehabilitation centre (Centro de Medicina de Reabilitação da Região Centro - Rovisco Pais) are involved.

3.3 Physical Infrastructure

The technological building blocks for the LUL environment include networking technologies and networked devices.

Networking technologies should facilitate the creation and deployment of new, value-added services. In that respect the NGN architectures are essential since they enable the use of multiple broadband, Quality of Service (QoS)-enabled transport technologies, in which service-related functions are independent from underlying transport related technologies. Furthermore, NGN architectures provide open interfaces and support a wide range of services, applications, and mechanisms based on service building blocks.

Major requirements for the networking technologies are: connection between different physical locations must be possible with the available services of NGN provided by commercial operators; the use of NGN and remote computing should allow the use of networked devices with very low computational power.

The devices to be networked include: the hardware systems to support the required servers; interactive terminals (Personal Computers), Personal Digital Assistants (PDA), game consoles, television sets, Set-top Boxes; domestic appliances; sensors, actuators and robotics.

3.4 Logical Infrastructure

Different devices use different infrastructures and different protocols for communicating and there must be a way for making the bridge between the different

protocols. There are some possible solutions for fulfilling this goal. One of the most promising ones is the NGN architecture. These open interfaces support a wide range of services, applications, and mechanisms based on service building blocks. This is the adopted solution for integrating the heterogeneity inherent to the Living Usability Lab (LUL).

3.5 Development Platform Architecture

Building open distributed systems that allow interaction among evolving heterogeneous devices has always been a complex task. Developers face several challenges such as interoperability, resource management, synchronization, performance issues, providing security, scalability and dependability. Specifically, an open system composes autonomously implemented and administrated software systems, which communicate over a public or private network. The composed systems may be implemented in different programming languages and deployed on different software and hardware platforms.

The generalization of the Internet and the diversification of connected devices have led to the definition of a new computing paradigm of service orientation: the Service-Oriented Architecture (SOA), which allows developing software as a service delivered and consumed on demand. The benefit of this approach lies in the looser coupling of the software components making up an application, hence the increased ability for making systems evolve as, e.g., application-level requirements change or the networked environment changes.

SOA can be described as a distributed architectural model in which applications are encapsulated into services that can communicate with each other through a communication system inherent to the architecture.

SOA architectures can be divided into different layers of abstraction so it can be discussed from a conceptual standpoint. The four basic layers include:

1. The **applicational layer**, which includes for example, older systems (legacy), Customer Relationship Management (CRM), Enterprise Resource Planning (ERP) or additional databases;

2. A **layer of services** where services are provided based on the applicational layer and normally through WSDL described interfaces;

3. The **processing layer** where services are **orchestrated,** that is, are composed in order to compose a file in the form of processes, for example in Business Process Execution Language (BPEL);

4. Finally, the **presentation layer** provides users SOA's functionalities through desktop applications or Web applications (portals).

SOA as architecture proposes itself to several objectives. One is the aggregation of complex business logics based on standard service interfaces, that is, to be able to obtain new service based applications through simple integration of the corresponding interface. With it, the business layer implementation is hidden and not so important for the development of applications.

A feature of SOA lies in its ability to enable inclusion of additional software in static and dynamic ways, thus ensuring that it will be easy to expand the architecture in the future if needed. As such, a recently published foreign service can be

discovered by the architecture and adopted as a component for building new software systems that in their turn may also be published and made available as new services.

The adopted SOA based architecture seeks a minimum dependence (loose coupling) between applications (components in the case of SOA), allowing therefore that they can be made available as reusable services.

3.6 Methodologies

The Living Lab is not just a repository of technologies. It is essentially an interactive environment in order to facilitate the research, development, integration, validation and evaluation of multimodal, adaptability and user monitoring technologies, new modes of interaction and new services supported by NGN. In this sense, the Living Lab necessarily has to propose and develop new methodologies, in particular for the specification of new services with a strong involvement of potential users, the **evaluation** of new services and the dissemination of knowledge.

During the specification user involvement can be achieved through [8]: idea generation; scenario development workshops; focus groups; brainstorming groups; nominal group technique.

The evaluation has several goals: evaluate process/ways of working changes; measure hard data of the improvements/changes; evaluate fit between software concepts (e.g. workflow, communication support) and users real way of working; evaluate acceptance, satisfaction, motivation and individual performance of users.; evaluate usability, bugs, functionality of software; create ideas about improvements and new features.

3.7 Applications

The only way to evaluate/validate the various "components" resulting from the project is their use in practical services and applications. New devices and service pilots are being developed based on technologies and will be evaluated.

3.8 Stakeholders

Real users are essential within the Living Lab context. They are contributors to the innovation process through initial ideas, evaluative feedback and improvement ideas, or just being users that allow to be observed or logged for evaluation. Therefore, they are central contributors to Living Lab because they are expected to be a source of ideas (creative role for the generation of radical new ideas), a mechanism for product improvement (creative role in an iterative product development process) and validation (evaluation role) as well as diffusion agents (marketing role). In our case, users are not only individual elderly end-users but also health professionals (e.g. gerontologists), developers of new services, ICT developers and institutional care providers.

4 The Architecture for New Services Development

As mentioned before, the architecture for services development adopts the paradigm of service orientation, which allows developing software as services that are delivered and consumed on demand. The benefit of this approach lies in the loose coupling of the software components that make up an application. Discovery mechanisms can be used for finding and selecting the functionality that a client is looking for. Many protocols already exist in the area of service orientation.

The architecture comprises three layers [9]: base middleware, intelligent middleware and applications.

4.1 Base Middleware

The base middleware contains the functionality that is needed to facilitate the operation of the networked environment. It provides the semantics to communicate and discover available services and devices in the network, including the ones that are based on existing communication and discovery standards. This implies that independence is accomplished for existing hardware and software and, therefore, new services can be discovered and composed.

Different devices use different infrastructures and different protocols for communicating and there must be a way for making the bridge between the different protocols. Therefore, the compliant device platform Interface allows algorithms to access the different devices (such as sensors and actuator) by a single interface that abstracts from proprietary properties of the device wherever possible.

4.2 Intelligent Middleware

The intelligent middleware layer contains the functionality that is needed to facilitate the usability and acceptance of the services. They broker between users and service providers, and provide context information, combine multiple sources of information and make pattern-based predictions. Information is tailored to user profiles and adapts to the user's situation and changes in the context: user modeling and profiling, user interface management, context awareness and notification.

4.2.1 User Modelling

User modelling provides the methodology to enhance the effectiveness and usability of services and interfaces in order to [9]: tailor information presentation to user and context; predict user's future behaviour; help the user to find relevant information; adapt interface features to the user and the context in which it is used; indicate interface features and information presentation features for their adaptation to a multi-user environment.

User modelling is a very broad research area with decades of historical development. In general, the concept of user modelling addresses issues of understanding users in order to make a system useful and make user-system interactions user friendly and universal.

As a variety of users may operate with the system, a user model is a representation of the properties of a particular user or group of users. More simply, user models serve as a description of the users of a system and a prediction of how they will behave and perform tasks. These goals are achieved by constructing, maintaining and exploiting user models and profiles, which are explicit representations of individual user's abilities and preferences.

4.2.2 Context Awareness

Context awareness is a property of a system that uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task. Different types of context can be distinguished [10]: device context (ex: available memory); user context (ex: localization); application context (email received, websites visited or preferences); social contexts (group activity, social relationship or people nearby); physical context (weather, altitude, and light). Not all types of contextual information can be easily sensed. Some types of contextual information (e.g. the mood or activity of individuals) can only be derived by intelligent combination of other information, or by human inputs [10].

To develop a context aware application it is necessary to address modelling of the storage and retrieval of contextual information [9]. For example, an RFID sensor in a room may provide information at several levels and to several applications. The provided information can then be used to indicate the presence of someone or to enable their identification or even to know their position. This requires context information to be understood by different applications. Thereby it raises the concern of its meaning [10].

The context awareness and notification modules will provide the basic functionality required to develop applications allowing people and other applications to stay aware of any significant change in context with minimal effort.

Work on context modelling and environment sensing started by the creation of a general webservice to manage, store and provide access by client applications. The first contextual information to this service is provided by agents producing information on the noise level in the environment of use, illumination conditions, and distance and position of the user regarding the display device. As a first use of this context webservice, an advanced adaptation of output modalities (text and speech) has been developed [11].

4.2.3 Multimodal Interaction

The focus of this intelligent component, nuclear for the Living Usability Lab, is to support interaction based on multiple smart artefacts with intuitive and natural interfaces that are multimodal. Usability and comprehension by end-users are crucial in order to create engaging and coherent experiences for users.

Speech input and output modalities have a key role in the development of natural interaction, particularly with non-specialists in the use of technological devices. In result, the project is dedicating great efforts in making available the necessary speech recognition and synthesis systems usable by European Portuguese older adults. In addition, a major effort already started in the creation of a Toolkit for the easier

inclusion of Multimodal Interaction in the new services envisioned for our Living Lab.

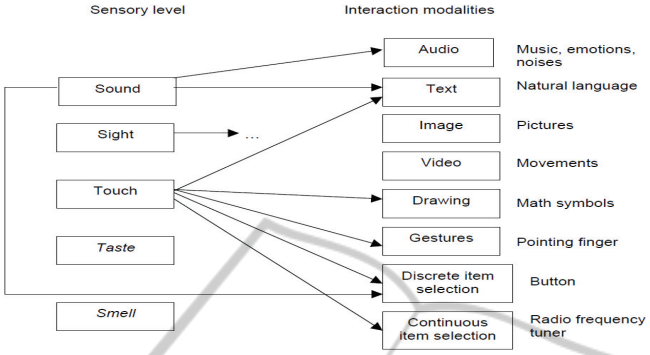

Fig. 2. Multimodal interaction.

4.3 Services and Applications

The application layer should allow dynamic services composition, which is essential to allow the congregation of different services to build domain specific applications. Therefore, the application services must be described based on a standard, commonly declarative, service description language to enable service discovery and invocation independently of its implementation details. This description is commonly syntactic and functional (i.e., the functional interface provided by the service in terms, for instance, of operations that may be remotely invoked). An example of a suitable service description language is the XML-based WSDL language, used to describe Web services.

Since the priority of the LUL translational research in the use of multimodal adaptable interfaces, NGN, and monitoring technologies to support people with special needs, AAL services for the older adults was the selected application domain to instantiate, evaluate and validate the proposed architecture.

5 First Results of the Project

In the first months of the project, started in April 2010, work contemplated:

1. Definition of Scenarios and Requirement Analysis [12] – Studies with users were performed to obtain information regarding scenarios and usability and technology requirements. One of the studies relates to the evaluation of existing Speech Recognition and Speech Synthesis systems [13]. Other study, involved a group of mobility-impaired individuals (paraplegic and quadriplegic) from Associação Salvador [14]. The goal of the study was to unveil usability issues and to derive design recommendations towards the development of future user interfaces that facilitate an integrated access to several communication and social media services

(email, agenda, audio and video conferencing, and social media services). Analysis focused on touch, gesture and speech interaction;

2. Definitions of the General Architecture - The results are reflected on the conceptual model and architecture presented in this paper;

3. State-of-the-art review [15] in: speech technologies for the Elderly [13]; Multimodal Interaction; Accessibility technologies for the Elderly; Next Generation Networks; Service Oriented Architectures; Cloud Computing and indoor and human care robotic applications;

4. Development of sensors and wireless communication for integration in a Home network. This work was essentially made by the companies PLUX and Micro I/O.

– Micro I/O has developed a wireless module and a gateway prototype, capable of providing reliable real-time short-range wireless communications in noisy environments, in particular those encompassing WiFi interferers. This company has also studied solutions to monitor events at a common dwelling, for example detecting when someone sits in the couch;

– PLUX developed a "Patient Tracking System" prototype – conceived to be used inside buildings, capable of monitoring continuously biosignals and location. The system consists of wearable sensors that allow the caregivers to monitor Heart Rate, fall detection, location and lock detection. Furthermore, the system has integrated a safety tool that enable the caregiver to have acknowledgment of abnormal situations and the end-user to trigger an alarm whenever needs for assistance. The results obtained with the system show that patients feel more comfortable and safe when are continuously monitoring and caregivers can optimize their time and provide a better and faster assistance to the end-user;

5. Video tracking, particularly on the evaluation of algorithms [16];

6. Development of a robotic platform, based on the improvement of the University of Aveiro/IEETA team of soccer robots (CAMBADA), in particular the design of new motor controller electronic boards and development of algorithms for navigation, object recognition and omnidirectional control (see for example [17]);

7. Start of the acquisition campaign of a new database of European Portuguese Elderly speech (see **www.doaravoz.com**) [13]. This is crucial to the training of speech recognizers for the target group of the project;

8. The first modules, essentially related to input and output modalities, to support the use of Multimodal interaction in the applications and services planned for the project were defined and developed;

9. Development of the first prototypes and SDKs/Toolkits- An SDK and prototype named Personal Life Assistant was developed [14]. Development of a prototype of a new Telerehabilitation Service [11].

6 Conclusions

This paper presents an overview of the Living Usability Lab Next for Generation Networks and relevant developments made during the first months of the project. This project is a Portuguese industry-academia collaborative R&D project, active in the

field of live usability testing, focusing on the development of technologies and services to support healthy, productive and active citizens. It is the first general description of the project made available to a general audience. Work in progress includes development of a multimodal interaction toolkit, creation of suitable evaluation methods and live evaluation of new services (ex: Telerehabilitation [11]).

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