

# TANGIBLE INFORMATION TECHNOLOGY FOR A BETTER AGEING SOCIETY



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## **Tangible Information Technology for a Better Ageing Society**

Proceedings of the CONFIDENCE 2010 International Conference:

Open Doors to ICT for Ageing and eInclusion

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# Tangible Information Technology for a Better Ageing Society

## Preface

The purpose of this volume is to present the contributions of European researchers in the fields of ICT and Ageing and eInclusion, to the CONFIDENCE 2010 International Conference. Information and communication technologies (ICT) addressing the needs of the older segments of the population attempt to support people to remain independent, to maintain an active participation in society, and to improve their quality of life. Populations are getting older in most countries. We can affirm that increased longevity is a great achievement of modern societies. However, there are threats to the wellbeing of modern societies coupled to this demographic change, such as the increasing dependency ratio, dispersion of nuclear families, organisation and management of care for older dependent people, maintenance of welfare systems and pensions, to name a few. Demographic figures illustrate the breadth of the landscape that we contemplate. The Statistical Office of the European Communities (Eurostat) predicts that by the year 2060 the population over 65 years of age will rise from 17% in 2008 to 30%. This situation will impose additional challenges to the older people and the society as a whole.

ICT is everywhere. With portable personal computers, Internet, and mobile communications (voice and data) we are experiencing more and more “ubiquitous computing”. The incorporation of hardware and software into products and habitats results in ICT based “smart” cars, and homes, for example. When these hardware and software components are everywhere but their presence and operation go unnoticed to the user, we deal with “pervasive computing”. The possibilities that ICT offers to us are enormous and can contribute to ease the lives of older people. Many of its applications can clearly contribute to the satisfaction of some of our needs.

A basic premise is that ICT is developed by humans and for the benefit of humans. Despite this, technology has been complex, difficult to use especially for non-experts, and hence not always acceptable. For reasons such as the lack of training in older generations, the need for a basic infrastructure, e.g. a personal computer and a connection to the Internet, it has also been inaccessible for many older people with or without disabilities. With research contributions such as the ones presented in the CONFIDENCE 2010 International Conference: Open Doors to ICT for Ageing and eInclusion, 9-10 December 2010, University of Jyväskylä, Finland, it seems clear that designers and developers are taking adequate steps to gain insight into the needs and limitations of older people. ICT applications designed with the needs of older people and other stakeholders in mind can contribute to the market success of innovative ICT applications. The reverse situation would not be so favourable, i.e. if we offer some ICT solution, which the potential older users do not need, they will probably not perceive any benefit and as a result they will not acquire it. If they perceive some benefit but the disadvantages of using that ICT solution are greater than the benefit they will probably not buy it or abandon it soon after.

In this book, Anne-Sophie Parent and Nena Georgantzi, provide recommendations to allow older people’s voice to be heard at all stages of research. They propose that this will contribute beneficial insights into how research will affect the wider community. Ethical issues in research and development activities within the CONFIDENCE project are presented by Narciso González, Anna Kämäräinen and Outi Kalla. In addition to the involvement of end users in R&D activities, this paper supports the tenet that ethical consideration since the conception of system concepts and throughout the projects can greatly contribute to successful ICT products and services. Kristina Larsson and Eva Bergström, suggest that a user-centric approach is important when developing a product not only to increase its appeal. User-centric activities are also means to create

understanding and curiosity among the end-users. This approach would supply the users with power to engage in future technical development that will affect their lives. Needs and requirements from potential users of the CONFIDENCE system are presented by Anna Kämäräinen, Narciso González and Outi Kalla. The authors also report on contextual demographics of the region of Jyväskylä. This contributes to understand the living conditions of the people who took part in these studies.

The ÆGIS Integrating Project, presented by Maria Gemou and Evangelos Bekiaris contribute the user centred design (UCD) approach developed in the project. The aspects of the design, development and deployment of accessible mainstream ICT are addressed in the paper. Additionally, they report the overall evaluation framework of the accessible ICT applications developed in the first 1.5 years of the project. Eleni Chalkia and Evangelos Bekiaris introduce the scope of the ACCESSIBLE project. It aims at enhancing the accessibility of ICT products in all applications by enabling large organisation, SMEs or individuals to produce accessible software products. The general scope and results are introduced through the basic outcomes, use case scenarios, and the evaluation methodology to assess the usability and utility of the tools. Automatic accessibility evaluation enabling frameworks are provided by Nikolaos Kaklanis, Panagiotis Moschonas, Konstantinos Moustakas and Dimitrios Tzovaras. They propose virtual user modeling techniques that enable the simulated accessibility evaluation of ICT and non-ICT products and services. This evaluation is performed at all the stages of the development. Kostas Kalogirou and Evangelos Bekiaris, report and analyse the feasibility of the design and architecture of an accessibility framework based on Java Micro Edition.

Fall risk assessment in ambulatory conditions is reported by Bart Jansen, Rudi Deklerck, Ivan Bautmans, Bart Van Keymolen and Tony Mets. Their results indicate that energy expenditure (derived from tri-axial accelerometer signals) during walking differs significantly between a group of elderly fallers and a group of elderly non-faller controls and is associated with walking speed. Diego Gachet, Manuel de Buenaga, Víctor Padrón and Fernando Aparicio present the Naviga Project. The main goal being the design and development of a technological platform that will allow elder people and persons with disability to access the Internet and the Information Society. Božidara Cvetković, Erik Dovgan, Boštjan Kaluža, Mitja Luštrek, Matjaž Gams and Violeta Mirchevska put forward the intelligent modules used by CONFIDENCE. These recognise falls and general disabilities and inform the emergency services when a hazardous situation is detected. It is proposed that older people would not need to move to other residence different from their own home because they will receive assistance when needed.

Leticia Zamora-Cadenas, Juan F. Sevillano, Markos Losada and Igone Vélez offer a novel positioning algorithm for indoor localisation systems that can be employed in ambient assisted living applications. They suggest that this algorithm is able to improve the accuracy of the position estimation compared to other solutions.

Abstracts of Interactive poster presentations include, The Personal Mobile Space (*Arjen mobiilipalvelut*), by Reija Kuoremäki, Tuula Nousiainen, Jukka Varsaluoma, Marja Kankaanranta and Pekka Neittaanmäki, is an ongoing research project which aims at developing solutions to support and promote well-being and learning with mobile technology. Two main concepts are addressed, exercise breaks in the work place based on an exercise program via mobile phone, and independent free-time physical activity. Juho Salminen, Helinä Melkas, Antti Karisto and Raisa Valve describe ThehStick – health stick – which is a modernised version of the so-called SOS Passport, in which various health-related data may be saved. It functions as a safety device in case of acute illnesses or injuries and a means for self-care and promotion of one's own health. A system to detect risk automatically is presented by Rainer Planinc and Martin Kampel. A single sensor unit is capable of detecting a wide range of risks. This will enhance elderly people's mobility and enable them to take active part in the self-serve society by reducing their fears.

Concluding, the contents of this book try to spread the notion that older people's needs must be taken into account even before an idea of any ICT solution is given the first consideration. This can be done through scientific reviews, surveys, interviews, focus groups, or a combination of techniques. The participation of



older people and their expressed needs could be considered the origin of ICT system ideas and developments. This in turn would likely result in useful, acceptable, ethical, and desired ICT products and services. It is our hope to be able to open the doors to ICT for Ageing and eInclusion to the most interested stakeholders, the older people.

Narciso González



## Full papers



# Ensuring A Fruitful Future to Innovation And Research

## Practical Guidance for the Involvement of Older People in Research Projects

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**Abstract—** AGE aims at giving voice to people aged 50+ so that projects and policies addressed to this particular target group are oriented by real user needs and a constructive dialogue between the different stakeholders can be achieved. While research and technology can advance on their own, they will have very limited impact and will result in minimum – if any – benefits for society, if user involvement is not taken on board. Allowing older people’s voice to be heard at all stages of research affords an insight into how research will affect the wider community. AGE’s guide [1] serves this multiple scope for present and future research both at national and European levels, always bearing in mind that older people are not a homogeneous group and that there is not a unique methodology of user involvement.

**Keywords-** *user involvement; guideline; ICT; ageing; older people; research; innovation*

### I. INTRODUCTION)

Ageing research is increasingly becoming a political and scientific priority and the involvement of older people has gained significant attention both in the research and policy field. This approach to involve users “reflects the democratic approach to participation (...) being able to improve the quality of their lives” [2]. Information and communication technologies (ICT), eInclusion and Ambient Assisted Living

(AAL) hereby play a central role, both in connecting older people’s lives with research

experiences, and in improving their quality of life. AGE Platform Europe (AGE) has finalized a concise and practical guideline putting forward principles and recommendations for user involvement that can be readily adapted by relevant stakeholders in their work. Building upon literature evidence, input from research projects as well as drawing from its own work in this field, AGE had the vocation to fill in some gaps and clarify the case for user involvement developing a toolkit addressed to researchers and project coordinators; older people’s organizations and individual users; policymakers and public authorities. Moreover, AGE wished to promote this guide through its network of member organisations, its research partners as well as various collaborating institutions at the European level. This paper falls under the attempt to reach the latter aim.

### II. OLDER PEOPLE AS USERS

The word ‘users’ is sometimes used rather vaguely which may create confusion about what exactly it refers to. Further complexity is created because literature and practice also use the terms ‘primary’ and ‘secondary users’, ‘end users’, ‘direct users’, ‘beneficiaries’ etc. In a very broad context, users are considered to be a group of persons who are expected to benefit from the developed service, product, technology or policy. Depending on the purpose of the research, the target group must be clearly defined. For instance, are family members who pay for the developed technology or service considered users even though they do not benefit directly from it? Should

paid social workers and informal carers also be included in the consultation? Researchers need to take notion of these different interpretations and decide which is/are the target group(s) that they should involve to achieve better research results.

Besides, innovating for an ageing population implies encompassing persons with different age, sex, ethnic and geographic origin, social and cultural backgrounds; with wide variation of cognitive and physical abilities; with different approaches and familiarity to technologies developed or services studied. Particular attention must be paid in order to avoid excluding marginalized users and/ or treating completely different situations in the same way: for instance, old age can span 20, 30 or more years so treating users over the age of 60 as a single group is unlikely to give rise to generally applicable findings. Thus a further ‘filtration’ of the user groups is essential. Restructuring smaller age-groups is considered necessary in order to respond to real-life situations. In addition, equal inclusion must be addressed: gender issues, situations of low income, the lack of access to transport, disabilities or low self-confidence must be taken into account.

In order to capture the heterogeneity of users and to ensure that all older people have equal opportunities to participate, an inclusive approach to user involvement is essential.

### III. WHY INVOLVE OLDER PEOPLE

Users have experiences, skills and abilities that complement the knowledge and expertise of researchers and policymakers [3]. Involvement of seniors becomes particularly relevant for users, researchers, industries and public authorities as they constitute an important society and market segment that stakeholders can no longer ignore. Of course user involvement is not a panacea; it requires additional effort and resources which may also delay research outcomes and decision making. So why involve users? What are the expectations of those engaging older people? Understanding *the impact of user involvement* is essential because the different reasons for involving seniors may affect the nature and the extent of user engagement [4].

While innovation and policy can advance on their own, this section argues that *genuine user*

*involvement*<sup>1</sup>, can bring an added value to research, policy and practice. Market deployment of the developed products and services is facilitated as real needs and problems are addressed; this obviously translates into cost benefits for the society as a whole. In addition, participation insofar as it means that older people are respected and feel valued is a key component of seniors’ wellbeing. In particular, older people can benefit from being involved in research in various ways:

- They are informed about research which concerns them directly, such as innovative solutions that can support everyday living at home or research findings on a mental disease;
- They become familiar with processes and methodologies and may even acquire new knowledge and skills. In fact, older people gain a better understanding of how research is framed and undertaken, what are the methodologies used and may also have the possibility to develop organisational, interpersonal or other skills;
- They have additional opportunities for social and political participation. In this sense they do not feel exploited by research and may gain confidence that they can make a change in the political and research scene.

Genuine user involvement also means that:

- Research ends up in results which are relevant for older people and which can be used in policymaking. As a result the quality and applicability of research is improved [5];
- Users accept the developed service or technology more easily;

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<sup>1</sup> The term *genuine user involvement* refers to user involvement which is meaningful and productive because it can influence research set-up, development and outcomes as well as decision-making in the policy field. It means conducting research or policy-related studies not for or about seniors, but with older people, or even undertaken by users themselves. In sum, *genuine user involvement* means that users are not involved only as subjects of the undertaken study but they assume an important role in it.

- Risk of ageism is avoided because older people are seen as valuable experts; Resources are invested on research which is important and can have an impact on the lives of older people.

In addition, if user involvement is organisation-based, a better dissemination of research outcomes may be achieved through the well-established network of contacts of older people's organisations.

#### IV. LEVELS AND METHODS OF USER INVOLVEMENT

There are various stages and levels of user involvement in research. AGE's guide presents some theoretical categorizations which may serve as models. However, in reality different methods and levels of engagement may co-exist. Of course, all approaches have strengths and weaknesses. For instance, while user-led initiatives give a strong say to older people and may be able to make fundamental changes (as older people are not only asked to evaluate but also to come up with new ideas), funding and resources can be problematic. On the contrary, research led by public bodies or other agencies is more likely to reflect already established research agendas and thus limit its impact but at the same time it may gain financial and other type or formal support and credibility [6].

Users may be involved at all research phases, from framing a research question to disseminating results and being part of a potential follow-up of the project. Obviously, there is a huge difference between distributing a questionnaire to older people and undertaking research where users are asked to play an active role. Some examples of user involvement include the establishment of *User Fora*, *Advisory Boards* and *Focus Groups*. The method that will be followed depends on the purpose of the conducted research as well as the available resources.

Even though there is no one-fits-all solution, as it has been demonstrated by various projects<sup>2</sup>, early user involvement is the best option for evidence-based research. In fact when user

participation comes at a later stage when the technology, product or service has already been concretized, there is a higher risk that the feedback from the users will not be implemented, especially when it requires fundamental changes in the prototypes which would result in significant additional costs.

In sum, a balance must be sought between the different approaches, by clarifying who takes the initiative, what are the expectations, what type of user involvement is feasible and in which stage older people will be involved.

#### V. CHALLENGES FOR USER INVOLVEMENT AND HOW TO OVERCOME THEM

Genuine user involvement is quite complex and encompasses many challenges: it means overcoming barriers, enabling people to use their own voice, engaging in a long-term creative dialogue with users, recruiting experts to carry out sociological work, etc. Meanwhile ICT and ageing raises new ethical questions related to the vulnerability of the user, the changing characteristics of the user population, budget constraints and the constant development of science and technology [7]. Some of these challenges are tackled by AGE's Guide.

##### A. Planning User involvement

Meaningful involvement in research requires planning and adequate resources; otherwise it is no more than a tick box activity. Preparing user participation includes refining legal, ethical and practical risks, defining roles and responsibilities for all parties, deciding on methodologies as well as timing and budgets.

User participation should be facilitated by various means: providing people with the necessary support and/or training; distributing material in a language and format that they can easily understand; making arrangements so that they feel comfortable, understand clearly the research issues and are able to participate effectively in the process; engaging qualified researchers who can encourage them, help them understand and observe them in real-life conditions in order to appreciate older people's needs. As some participants may lack confidence or familiarity with the methodologies used or the

<sup>2</sup> Among others : ERA-AGE, FORTUNE, USEM, FUTURAGE, OASIS, Dreaming, Mediate

topic studied, empowering people to use their own voice is a crucial factor.

Limited time often hinders meaningful user involvement. Planning should ensure that timescales for involving users (for recruitment, participation and evaluation) are realistic. Sometimes the need for funding of user involvement is underestimated: users are often expected to contribute with their time and expertise for free while project partners get paid for their contribution. While remuneration might be envisaged, especially for long-term user engagement, users are often motivated to participate on a volunteer basis, as long as their basic expenses are covered. However, users should not be asked to pay any extra fees for participation in the project. If some of the users need personal assistance, special arrangements should be made to support their participation by covering all or at least a part of their expenses.

When searching for a suitable venue, besides budgetary concerns, accessibility issues should also be addressed; especially when working with older people, providing a place with sufficient air and light, as well as clean and accessible entrance and toilets is particularly important. Regarding the organization of meals and coffee breaks for participants, dietary needs should not be neglected. In addition the food should be adequate and culturally appropriate.

When planning user involvement, all relevant legislation, regulation and ethical codes should be taken into account; it has to be defined in details how these provisions will be met in terms of processes, timing and responsibilities and it is important to raise them during the planning phase, otherwise in case a problem arises, it will be hard to remedy and it may even have legal consequences.

Some key ethical concerns include the following:

- Consent of the end-user
- Objectives of research and benefice to the user
- Safety

- Independence of research and researcher
- Respecting decisions, dignity and integrity of user
- Gender balance
- Equality
- Privacy and data protection

Copyright issues have to be clearly defined, including whether users can make use of the acquired information and knowledge. All those participating in the process have to be able to see the outcomes of their contribution. In addition, users should be acknowledged in any work that arises from the user involvement process.

The provisions regarding the lawful processing of personal data have to be respected even if the users have given their consent. Especially regarding sensitive data, like physical or mental health, sexual orientation and ethnic origin, more restrictions apply. As European States may interpret the scope of the European instruments quite differently, special attention should be given to national legislation.

To avoid risks related to the processing of personal data such as identity theft, profiling or constant surveillance, the principle of proportionality has to be respected. Data can be used only for the initial purpose for which they were collected. Anonymization or pseudonymization are ways to prevent violations of privacy and data protection rules. Processing has to be limited to what is truly necessary and less intrusive means for realizing the same end have to be considered.

#### *B. Recruitment*

The selection and recruitment of users is a crucial part of the user involvement process: depending on the subject of the study undertaken, the target group and the representativeness of users have to be clearly defined. Representativeness may depend on some of the following factors [8]:

- Age
- Socio-cultural and ethnic backgrounds (profession, ethnicity, nationality, community, etc)



- Physical and cognitive ability
- Sensory ability (hearing and vision)
- Personal circumstances (living arrangements, income, etc)

Besides, when selecting users, the risk of high percentage of drop-outs should be taken into account, especially when dealing with older people and frail users<sup>3</sup>. To enhance user participation and avoid last-minute withdrawals, users need to agree on the ethical code managing the trial and to be informed and trained to the use of prototypes of devices and services before the beginning of the trials. User involvement means investing in users and consequently drop-outs have a substantial impact.

Using appropriate language and modes of communication are also important factors in the recruitment process. To approach users, linguistic and cultural differences need to be addressed; personal contacts, meetings in local communities, telephone discussions are good alternatives to emails which in most cases can reach only a small part of the senior population. Another good practice is the use of peers, professionals, younger people that the involved users can trust and whose experience can encourage them [9]. In order to induce motivation it is essential to make users understand that their contribution is valued; knowing how their opinion will be used to make a change, will persuade people to get engaged.

### C. *User Involvement in practice*

Striking a balance between users' and researchers' knowledge, experience, priorities and expectations is definitely not an easy task. It requires a lot of time and commitment but at the end it will have the most important effect on the quality and the impact of the undertaken activity [10].

The stakeholders involved need to build a partnership based on respect; trust among the different parties has to be ensured from the early beginning and users should be treated like experts.

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<sup>3</sup> The Dreaming project (Elderly Friendly Alarm Handling and Monitoring) experienced the impact of drop-out in clinical trails. A consistent revision of the trials became necessary and it led to the remodeling of timing, budget and trial's structure, too. More information: [www.dreaming-project.org](http://www.dreaming-project.org)

This includes, being flexible on the agenda as topics which were not decided by researchers may arise. Unless, users are given the possibility to significantly alter what has been already defined and decided before their participation, one cannot claim of undertaking genuine user involvement. Differences and gaps in communication is a central issue that needs to be addressed. Concepts need to be simplified and explained; users need encouragement to say what they want but also guidance to avoid navel-gazing; observing and empowering older people is an essential element for effective user involvement; narratives or dramatization may also be used to stimulate discussions. Users should also have the possibility to opt-out and this is not necessarily a failure; on the contrary, it should be valued and analyzed, as the opt-out can say more than an unfruitful involvement.

Alongside a good relationship between researchers and users, disseminating results broadly through various appropriate channels and engaging users in evaluation and peer review processes are essential elements for efficient innovation [10].

## VI. CONCLUSIONS

User involvement is an important but complex issue. First, older people are not a homogenous group; researchers should aim to conduct research designed to be inclusive and representative of various user groups. Second, the methodology for user involvement depends largely on the discipline and the study design. Besides, undertaking interdisciplinary research is a challenging field that requires optimal cooperation among the different stakeholders.

Older people should not only come to validate the research question; their role should be gradually enhanced: from subjects of research, to active participants and further on to framers of the question and co-designers of research. Besides guaranteeing user involvement at all stages, ethical and legal concerns should also be tackled. Indubitably, personal contact is essential when working with older users as well as empowering them to understand and use their own voice to express needs and ask questions. The role of user

organizations is particularly important as well as undertaking a plan that ensures sufficient time and resources for user involvement. Last, collaborations between the research and the user community should be promoted, increasing in the meantime the opportunities for dissemination of the research outcomes.

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# Ethical Research and Development in the CONFIDENCE Project

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**Abstract**—Information and communication technology (ICT) developments are targeted as means to reduce the burdens associated with an ageing population. The project CONFIDENCE aims at extending the independence of older people beyond what would be possible without technological support. The goal of this paper is to present the ethical issues that appeared relevant at the concept development stage and during the project. One ethical dimension is directly associated with the technology and must support principles such as human rights, privacy, safety, and dignity. The other ethical dimension is the voluntary contribution of people as participants in research activities. Ethical review of research plans and informed consent of the participants must be observed in this domain. We conclude that observing ethical principles since the inception of concepts and during the development process can empower users to make informed decisions on the acceptance of ICT systems and services once these become available.

*Keywords* –Ethics, informed consent, older people, CONFIDENCE

## I. INTRODUCTION

The population of the world is growing older and the dependency ratio is increasing in parallel [1]. This demographic phenomenon imposes socioeconomic burdens on the older people, their caregivers, and the health and social care systems [2]. Information and communication technology

(ICT) developments are considered as important contributors to reduce these multilevel burdens. See e.g. [3].

The project Ubiquitous Care System to Support Independent Living (CONFIDENCE), aims at enabling older people to live in their preferred environment, i.e. their own home, as long as possible with the support of ICT technologies and services. In brief, the system will be able to identify harmful situations, such as falls, and anomalous conditions such as reduced functional ability in the performance of activities of daily living (ADL). Wearable radio frequency (RF) sensors and communication channels are the technologies that support these functions. A more detailed description of the system is presented in [4].

The successful development of this system cannot be conceived without the involvement of the users. This is, the older people and other relevant stakeholders. This technology involves motor behaviour monitoring and the transmission of information to emergency services or other designated people. This information can be considered sensitive as it includes personal identification and the condition of the person, e.g. the person has fallen down. In these situations, the adherence to ethical principles is of utmost importance.

This paper reports the ethical issues that appeared relevant at different stages of this multidisciplinary research and development activity. Figure 1 summarises the most relevant ethical dimensions addressed within the project and presents some

examples of situations in which this or similar systems could be misused.

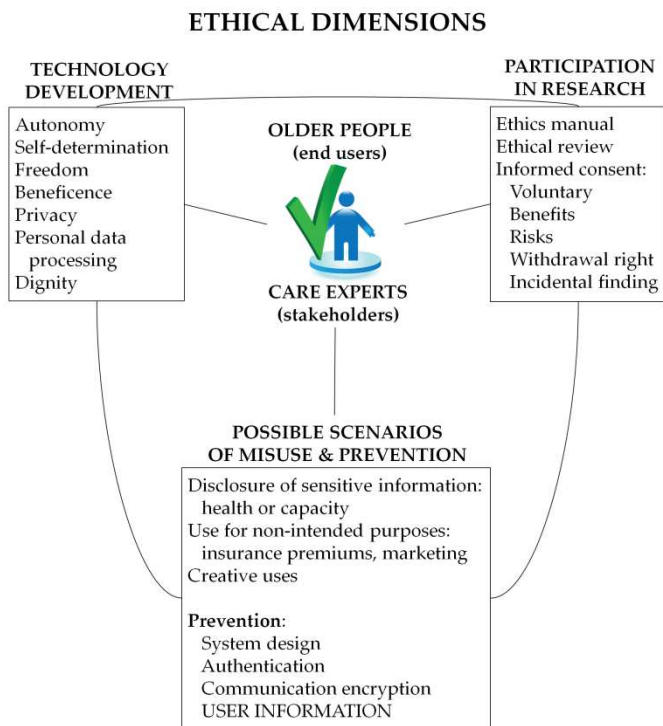


Figure 1: Ethical dimensions and aspects considered in the CONFIDENCE project including a sample of potential scenarios of misuse and preventive strategies.

One ethical aspect is directly associated with the technology under development and how this can affect the potential users when it becomes available on the market. Issues such as human rights, safety, privacy, integrity, and dignity are reported in section 5.1. The other ethical aspect within the project is the voluntary contribution of people as research participants. The main conditions to be satisfied by researchers concerning the approval of research plans by an ethics committee, as well as the issues to consider in the informed consent obtained from research participants are described in section 5.2. Older people and care experts opinions on the respect of principles such as privacy, autonomy, integrity, and dignity of the end-users are provided in section 5.3. Some scenarios in which this type of technology could be misused are presented in section 5.4. These aspects can be extremely important also for other research and development projects using the same or analogous technologies, as well as for commercial applications. In particular, researchers in the areas of ambient assisted living

(AAL), ICT and ageing, eInclusion, and eHealth could benefit from the results of this research.

Additionally, an adequate consideration of the potential ethical issues that can emerge when an ICT system or service is taken into use may contribute to improve user acceptance of the technologies and services. Consequently, a business advantage for such systems could be expected.

## II. OBJECTIVES

The goals of this paper are:

1. To present the ethical issues that appeared relevant at the concept development stage, as well as those which arise during the project
2. To raise awareness of the potential scenarios in which the technology adopted to implement the CONFIDENCE system might be misused

## III. METHODOLOGY

The methods used in this study at the concept development stage were reviews of the literature on ethics and research papers related to technology and functions analogous to the CONFIDENCE system. These included technologies such as radio frequency identification (RFID), care systems, personal emergency response systems, and social alarm systems. Data were also collected from voluntary participants through semistructured interviews with older people living independently and focus groups of care service experts. Similar research activities were carried out in Italy and Sweden. In this paper only the results obtained in Finland are reported. Twenty three and 10 older people participated respectively in 2 needs and requirements elicitation researches. Semistructured individual interviews were used to collect information from end users. Care experts participated in focus groups also in 2 research occasions (respectively 10 and 5 experts) with similar requirement elicitation purposes. Both end users and experts provided their opinions on the compliance of the system with ethical principles in addition to the questions directly addressing the requirements for the system.

## IV. SYSTEM DESCRIPTION

The CONFIDENCE system prototype consists of wireless RF sensors/tags, a processing unit or base station, and a portable device. The portable device

serves as the interface between the user and the system. The software modules localise the tags worn by the user in the 3 dimensional space, reconstruct the bodily position of the user, and interpretation algorithms discriminate among normal, emergency, and increased risk level situations. The users are able to control whether the alarms are forwarded to an alarm receiver or not. The intelligence and predictive capabilities of the system represent some of the main innovations of CONFIDENCE.

## V. RESULTS

### A. *Ethical aspects in the development of ICT*

Most of the ethical issues related to research with human participants are well grounded. However, when technological innovations are considered, such as CONFIDENCE, there might be issues hard to foresee and arduous to handle. At the beginning of the project, we reasoned that the system ought to support principles such as basic human rights, safety, privacy, integrity, and dignity [5]. It also became apparent that the European and national regulations on personal data processing were relevant [6], [7].

Freedom is perhaps the most valuable of the human rights achieved by human kind. The technology employed in this system shall respect the freedom of choice of the user. The user will be able to decide whether to use the system or not. This might seem obvious. Naturally one has the right to switch on and off the TV for example. Nevertheless, in the future of interoperable health and care ICT products and services the freedom to use a certain component of the system or not, e.g. a monitoring device which causes inconvenience to the user, might not be so clear. For example, the end user may be responsible for handling appropriately a number of devices in order to obtain an adequate level of care or health service. It can be assumed that the service received depended on the concurrent operation of e.g. 2 devices but the end user switched off one of these. In this context, the service provider could be exempted from responsibility in the case of failing to handle an emergency occurring to the end user. We could imagine that the device the end user switched off, jeopardising his or her safety, was the only one providing user access key to the service. Undoubtedly, this hypothetical case should be

prevented by a system which demonstrates sufficient transparency and operative robustness.

The system collects and processes information concerning the users, i.e. 3D bodily posture and motor activity acquired through (RF) tags and sensors. See e.g. [8]. Initially, the mechanism implemented by CONFIDENCE to comply with data processing regulations has been to assign the role of data controller to the user. This is, the data collected and processed by the system belongs to and is managed by the user.

Privacy is also respected because the system is not intended to share or provide data to other systems or services. A commercial product based on the CONFIDENCE prototype, might well involve different service providers and interoperation with other care or health systems. The mechanisms to assure respect of privacy in this context should be reanalysed and redesigned as the original settings would not suffice. Ethics and privacy issues in the context of Ambient Intelligence systems can also be found in [9].

The information is relevant for detecting falls and other behaviours that may relate to health problems, and to summon help when there is an emergency. It can be assumed that the principles of beneficence, purpose, and proportionality are satisfied by the current state of development.

The user controls whether an alarm procedure is initiated or not, except when the person is not capable of acknowledging this situation, for example, when the person is unconscious. In the latter case, the system initiates the alarm without the explicit consent of the user at this particular moment. Information and training to the user before adopting the system should guarantee that the informed consent of the user for this situation has been declared in advance of these potential hazardous events.

### B. *Ethical aspects in the research with humans*

Many scientific disciplines employ human beings as subjects of research. The pioneering field in which ethical guidelines appeared to safeguard the rights of the human participants in research was medicine [10]. Other disciplines such as the social and behavioural sciences, and engineering have followed [11], [12]. These have also provided their associates with codes of conduct and ethical

guidelines to ensure that research with human subjects does not use the right to freedom of research beyond the rights of the participating humans. Freedom, respect for life, justice, beneficence, and privacy are the most salient human rights contemplated in ethical guides.

The project consortium is multidisciplinary and brings together several social and cultural backgrounds. The countries represented in this research team are, in alphabetical order, Finland, France, Germany, Italy, Slovenia, Spain, and Sweden. At the beginning of the project, an ethical manual was elaborated [13]. This serves as the common ethical reference upon which the different disciplines and cultures can rely upon in order to deal with the ethical issues that may arise during the R&D process. Several research activities within CONFIDENCE required the participation of older people, health and social care experts, and family members, or others providing care to older people.

Following a pragmatic approach, two of the partners carrying out research with human participants have established internal ethical committees for this project within their organizations. We, the authors of this paper, direct ethical enquiries to the institutional ethical committee of the university. Ethical approval for two needs and requirements elicitation studies has been obtained from the respective ethical committee of each research site.

During the information consent process, the information sheet and the informed consent were offered to the participants. A requisite for participation in the research was to read and listen to the information provided by the researcher, confirm that the information had been understood, and sign the informed consent form. The information sheet indicated that their participation was voluntary and invited them to read the explanation of the studies. This also stated the purpose of the research, the procedures involved, the potential benefits, risks, discomforts, and precautions of the research. It also described the alternative procedures available to them. In our case, it was indicated that no alternative treatments were available, as these studies did not involve treatment to the participants. The right to withdraw from the study at any time without consequences was also stressed. Confidentiality and anonymity of the information they provided was

assured. Their identity will not be disclosed in scientific or other publications, or to third parties. The participants were also reminded of their rights concerning the processing of personal data.

Another section of the information sheet considered the possibility of obtaining incidental findings. These are considered those research results which occasionally arise unexpectedly in the course of a research and are unrelated to its original purpose. These may have significance for the health or well-being of the research subject. Often, incidental findings are associated to biomedical research but can appear in other fields as well. Therefore, the participants were asked how they would like the researchers to handle the incidental findings if these would occur. The participants were asked whether they wanted to be informed or not. Finally, information and contact details were supplied about the persons they could contact concerning the research, i.e. the principal investigator, and the ethical committee which had approved it.

One issue raised by these ethical reviews has been the comprehensibility of the information provided to the participants describing the research. Therefore, we modified this information to ensure that the participants understood unequivocally the purpose of the research and their role. Further research such as usability studies with prototypes of CONFIDENCE will follow similar ethical review procedures to safeguard the rights of the participants.

The researchers invested efforts into describing the CONFIDENCE system in such a way that the essence of its components and operation was maintained while the participants comprehended this technology. For example, the technical references to communication protocol standards were obviated in order to reduce the complexity of the information. This is, the older people and experts understood the principles involved in the RF communications used for the localisation of tags in space. Adding references to the particular standard protocols employed by the system would only cause unnecessary distraction of their attention in the research situations.

### C. Ethical concerns of the research participants

In the beginning of the project, 23 older people participated in individual semistructured interviews aimed at collecting information about their needs and requirements for the design of CONFIDENCE. When the end users were asked for the first time about integrity, 18 of the 23 end users considered that the system could violate their integrity. In a follow up question, they characterized their answers about integrity as an abstract concept. Some manifested that the relevance of the system to the end user may justify the use of this technology. Quoted from two end users, they thought that the “system does not violate privacy, if the information collected is confidential” and “if obtaining help relies on the technology, it doesn’t violate integrity”. However, they also thought that constant monitoring could violate their privacy.

The participants had positive attitudes towards using tags at home. Twenty respondents would use tags. Similarly, 19 of 23 would accept the presence of tags in clothes.

Semistructured interviews with end users at a later stage of the project involved 10 participants. Eight participants thought that the system would not violate their privacy or integrity. However, 8 participants preferred hidden sensors and tags. Our interpretation is that unnoticeable devices would help them to maintain their dignity. For example, visible signs of care technology on them, i.e. RF tags, could denote physical or psychological weakness in front of other people. If these devices could not be perceived or interpreted by others as care technology the self-esteem of the user would not be affected.

The participants had doubts about who could access the information and if it could be possible to misuse it. One participant pointed out that legal aspects should be considered carefully and formulated “who is allowed to investigate the location of the user?”

Additionally, we asked the participants to provide their opinions about the ethical issues that could arise from using CONFIDENCE. Care experts, who participated in focus groups and end users reported that the system, as presented to them during these research activities, seemed to respect the rights of

the users in terms of privacy, autonomy, integrity, and dignity.

### D. Possible scenarios of misuse

Within the consortium, we attempt to maximize the ethical compliance of the results of this ICT project. Therefore, we research, explore, and suggest options to prevent possible scenarios of misuse of this technology. In the following paragraphs a non exhaustive set of potential cases where this or similar technologies could be misused are presented.

One case, as pointed out by end users, concerns the disclosure of information concerning the ADL of the users. For example, family caregivers might obtain information from the care system about how the older person is doing by default or by setting this feature on the system, e.g. how long time the user is staying at home or how long time this person is going out. Under normal circumstances the users might tell these caregivers about their whereabouts by own initiative. However, in some other circumstances the user might want to keep this information private. In the latter case the user must be able to easily, i.e. not requiring advanced knowledge of the operation of the system, switch on and off the capability of the system to share this information with another person. Yet still in some other circumstances doing so might represent a hazard for the user. Imagine a user with limited cognitive ability that becomes disoriented when leaving the household and is incapable of returning back without assistance. Some ethical dilemmas can emerge even though attention had been paid to these issues in the design and development process of a given care system. By design, such a system could support the rights of self-determination, autonomy, and privacy of the user in some circumstances. On the contrary, under subtly different circumstances some or all of these user rights, including freedom, might not be guaranteed. The rights of the end user might have been handed over to a legal custodian or representative. This could be the case when the rights of the person are in conflict with his or her personal safety. Further elaborations on the use of RF identification and its implications on privacy and freedom can be found for example in [14].

Another scenario that we have considered is the use of information collected by the system for purposes for which it was not intended. A case can be considered where a health insurance company has

provided a system such as CONFIDENCE to the older person. The purpose of the system as informed by the insurance company would be to allow the person to obtain help when is needed whether the user is able to summon help or not. The insurance company also has information about the functional ability of the person and by means of this information decides to adjust the coverage or the premium of the insurance policy. There should not be any argument against this practice if these conditions are crystal clear to the user when the insurance agreement is made. In other circumstances, the ethicality or the legal validity of this practice would probably not be supported. By own experience, the terms and conditions of insurance policies are, in general, complex and difficult to understand for the vast majority of the non-professional customers. Therefore, in general, clear and understandable terms and conditions of the insurance providing the system must be guaranteed.

Profiling the user by means of the information gathered by the system for purposes such as advertising or selling products or services must be prevented. This case also falls within the realm of using the system for unintended purposes. A hypothetical situation could materialise with relative ease if we consider the business of proximity marketing enabled for example through Bluetooth connectivity. Self-determination, autonomy, dignity and freedom could be at stake if the users are not informed and have not consented unequivocally to receive this form of advertising. There are similarities with the phenomenon of spam e-mail messages that we experience so often or the unsolicited telephone calls and direct mail marketing that was more prevalent a few years ago.

There will be situations beyond the capacity of the technology to prevent misuse if the users are not aware of the risks involved and the protective actions that they can perform. Furthermore, the users will likely find new uses for which the system was not conceived. To prevent situations like these, the only precaution possible is to ensure that the user is properly informed about the functions of the system and the possible hazards.

## VI. CONCLUSIONS

The CONFIDENCE project continuously considers ethical issues and data processing

regulations from the outset. The partners in the consortium are aware of the ethical issues that may appear as a result of the technologies employed in this R&D activity, and as the users interact with the system. Ethical committees review and provide opinions on the research plans involving human participants. Their opinions have been used to improve the comprehensibility of the information presented to the participants. They cannot make free decisions when the research situation is not completely understood. These have also reassured that the research procedures would not jeopardise the rights of the participants or harm them. According to the opinions of research participants, personal data processing, privacy, and dignity do not seem to be at stake within the development of the project.

The system, as a possible commercial product, shall implement each of the available mechanisms to protect the privacy, dignity, and safety of the older people. Misuse of the system shall be prevented through design and information to the users specifying how they can contribute to maintain their privacy and safety. As a corollary, assistive ICT aimed at supporting older people's independence shall include privacy enabling mechanisms such as access keys and data encryption as minimum specifications.

The contribution of voluntary participants to this project is an invaluable resource towards the development of ethically compliant technologies such as CONFIDENCE to assist older people in the maintenance of their independent living.

We trust that our dedication to ethical issues during the project will transfer to ethically compliant and acceptable commercial applications for the benefit of older people. Products and services that do not comply with ethical principles, such as the ones described in this paper may render ICT products and services unacceptable for potential users or customers. The reverse could significantly contribute to the success of the product in the market if other necessary requirements are also satisfied, e.g. utility, usability, acceptability, and affordability to name a few. This is also applicable to AAL, eHealth, and other ICT systems which may impact on the freedom, privacy, and dignity of the person.



We would thus recommend to take an ethical standpoint from the start of any ICT concept formation, e.g. AAL or eHealth, systematically. The potential end-users, and other stakeholders, e.g. formal and informal caregivers, health professionals, service providers, should be consulted. The information collected should then be translated into the technical specifications and implementations. Development cycles representing changes in the original plans should be accompanied by a revision of the ethical issues through the consultation of users and stakeholders. Additionally, providing comprehensible and sufficient information to the users will be the only means to allow or empower them to make informed decisions. Finally, this process will support their dignity, privacy, and freedom also when they consider acquiring AAL, eHealth, or other systems and services to support their independence and participation in society. In our opinion, this could make a difference between successful and unsuccessful commercial systems.

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# The End-user in the Focal Point

## Methods for a user-centric approach in Umeå

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**Abstract**—The end-users targeted in the CONFIDENCE project are people at the age of 65 years and older, living in their own home, with no difficulties in their activities of daily living but with fear of falling, and therefore at a risk of isolation. The targeted end-user is a versatile and multifaceted group, ranging from elderly with an active lifestyle participating in numerous activities at a weekly basis, to elderly isolated from social interaction and physical activities. Experiences of technological solutions, health status as well as life style in general differ among the individuals in the group. A user-centric approach is important when developing a product not only when it comes to being appealing to the targeted user. But also as a way of creating understanding and curiosity among the end-users and to empower the future users in engaging in the technical development that will be a vital part of their own life. This paper will present different methods and considerations used within the CONFIDENCE project in order to gather requirements and ideas from the target group of the project.

*Keywords-component; User-centric approach, end-user, methods, empowerment, participation, development*

### I. INTRODUCTION

The development of the CONFIDENCE prototype is a user-centred process. Throughout this process Umeå Municipality has established a platform for discussing and developing technical solutions in co-operation with representatives among the elderly population in Umeå. As a care giving

organization, paid for by taxpayers, Umeå municipality is able to involve people among the target group using existing networks and structures inside the organization. The role as caregiver also situates the relationship between the project and the end-user in a different way than as, for example a university, making every contact between the project and the end-user representative sensitive for errors and misunderstandings.

In the planning of how to involve end-users, the Umeå Municipality has taken inspiration in the work of Luleå University of Technology and the municipalities of Luleå and Boden as these entities have been working successfully with the elderly population for years. The doctoral thesis written by Anita Melander Wikman has provided new ways of thinking when involving targeted users as well as the understanding that Information and Communication Technologies (ICT) can be used as a tool for ageing well if the methods used is empowering of elderly people [1].

### II. WHY USE A USER-CENTRIC APPROACH?

The need for a user-centric approach has been more and more appreciated by the European Union when funding research projects as well as researchers and developers trying to develop products for the market. There are two different aspect describing why the future user should always be in focus when developing and designing technological products. One aspect is the users themselves, the other aspect is the finished product.

#### A. *User-centric approach for the sake of the future product*

The development of ICT designed to fit into the life of a future user has to capture the life and

expectancies of the targeted user. No ones are better suited to answer to the requirements needed in a proposed system than the targeted user them selves. A product that does not live up to the standards set by the thought of user or buyer is not likely to have a chance on the market. This is why the research and development should be very intoned with the target group, respecting the ideas and considerations brought up by the end-users at an early stage in order for the final product to be as close to the targeted end-user as possible. Simple mistakes can be corrected at an early stage if end-users are involved from the beginning of the process.

#### *B. User-centric approach for the sake of the future end-user*

The other aspect is the user. Without giving the targeted end-user a chance to participate in the creative process of a proposed ICT solution the user can feel alienated from a final product. The end-user may feel insecure and afraid of the product and the system may not work as fluidly as it could have given that end-users had the opportunity to influence the development of the system.

ICT can be a tool of empowering for elderly people, giving elderly people the opportunity to lead an active life at a higher age or ease the burden of activities of daily living. With a user-centric approach the whole process of developing a system can be empowering, letting the elderly engage with the technology and learn about research projects and product development.

### III. ACQUIRE KNOWLEDGE ABOUT ICT

#### *A. Create confidence and understanding*

To establish a link of communication early on in the project Umeå municipality informed the municipal pensioners committee, a committee gathering the local pensioners' organizations and politicians from the city council, at the application stage of the CONFIDENCE project. This contact was important in order for the project to be known among the organisations representing elderly people at a local level. But also in order to involve the target group early on in the process.

One key point for the project has been to let the end-users get as involved in the process of the project as possible and that they feel confident that their participation will be communicated to the

project group. When feeling confident in the process the participants are able to share more of their ideas and questions.

#### *B. Create knowledge and curiosity*

In order for the involved end-user representatives to give usable feedback on the CONFIDENCE system they have to have some knowledge about ICT and technical solutions designed to be placed in a home of a user. Descriptions of the system and references to similar solutions have been key points in this work to enable the end-users to comprehend the information given by the project during interviews and tests.

When the end-users start to understand the technology behind the system they become more involved in finding solutions and alternatives that would suite their life situation. This also generates curiosity for knowing more about technical solutions and what can be done to ease different situations in the life of elderly.

#### *C. Handling fear of technology*

One important aspect of technology is the sense of insecurity it can arise. For some elderly it could be explained by the lack of experience of highly technological solutions. For others the insecurity can rather be explained by the fact that technology in different ways do not live up to the expectations and requirements of the user when it comes to functionality, security and integrity.

An additional important aspect is the fact that a technological solution designed to support a user in different ways also concerns the potential user emotionally. A part of the natural ageing is that some abilities taken for granted deteriorate or even vanish. These effects of ageing can be hard to comprehend, to be comfortable with and to accept. The introduction of aiding technology can be experienced as a provocation or diminishing of the person's abilities.

With these aspects in mind the introduction of the technology in terms that the target group can relate to is of up most importance, along side with a user-centric approach that allow the end-users to express their fears. In respect of these expressions the Umeå project management has drawn attention to these aspects in the national reports capturing the results

from the individual interviews and the focus group interviews [2, 3].

#### IV. PLACES TO MEET

How the meeting between end-users and project workers is situated is a key question when it comes to create a situation where the informant is not put in a weak position. To avoid this the project management in Umeå used different arenas where representatives from the end-users can be found. Different methods for interviews were also used in order to gather as much feedback as possible in environments that promote cooperation and curiosity.

##### A. Established arenas for elderly

One important link of communication between the municipality and the local pensioner's organizations is the municipal pensioners committee. The committee holds four meetings a year and has an advisory function in relation to the city council. The project has visited the local pensioners committee at least once a year since the beginning of the project. The project has then updated the committee on the development of the project and asked for opinions and suggestions.

Another forum for elderly people in Umeå is the "Seniorvimmel" event hosted in the city hall by the local pensioners committee and the department of social welfare services. The event attracts hundreds of elderly with exhibitions, seminars and information targeted at the senior population in Umeå. During the first event in November 2008 CONFIDENCE had an exhibition stand with information about the project and the system. During the day many elderly visited the stand and asked questions. Some people also took the opportunity to make suggestions for the system.

##### B. Individual interviews

During the first part of the project the end-user partners gathered end-user requirements for the development of the system using individual interviews as the method. The interviews were structured with a common protocol for all end-user partners to follow capturing health status and social activity alongside with requirements for technology situated in the user's private life.

In order for the interviewee to feel comfortable the project management in Umeå invited the

interviewees to a neutral place at the premises of the municipality. Some interviews were done in the home of the interviewee. The interviews took from one hour to over two hours, giving the interviewee time to answer each question thoroughly. One important task for the persons managing the interviews was to listen and to ask for further explanation when needed. Many of the meetings between the project and the elderly volunteers during the interviews can be characterized as heartfelt and honest, surfacing private matters as well as useful feedback on the CONFIDENCE system.

The results from the individual interviews were given back to the participants via a report in the native language as well as the English deliverable.

##### C. Interviews in groups

One year after the first interviews the end-user partners once more gathered feedback from the end-users. This time the system had developed and could be presented to the end-users. A common method for gathering feedback from a targeted group is focus group interviews. Umeå had three groups with 4-6 persons in each group. The advantage using focus groups is that the participants can bounce ideas off from each other taking the discussion much further in a shorter period of time. This method also allows the interviewees to learn about ICT by discussion not only with the project management but also among each other.

The results from the focus group interviews are assembled in D1.3, which also were spread among the participants.

#### V. CONTINUOUS DIALOGUE

A key to keep up the interest among the end-users and to be able to get fast feedback from elderly is to always have open channels between the end-users and the project. This has been done in different ways in Umeå.

##### A. Newsletter and project web site

The project has a Swedish newsletter that informs end-users and local stakeholders about the current status of the project. The newsletter is sent by mail to the elderly who have signed up for it and by e-mail to among politicians and stakeholders in Umeå. The newsletter is not only a way to inform about the project but also a way to make sure that people

interested in the project get proper contact information to get in touch with the project management in Umeå.

Another way to have a continuous link of up to date information is the Swedish CONFIDENCE web site managed by the project at the Umeå municipality domain. The site contains newsletters, the Swedish national reports in Swedish and English as well as links to the international CONFIDENCE web site and the project partners. During the first two and a half years the web site has been viewed over 26 000 times.

#### *B. Always open for feedback and ideas*

One thing that have been successful for the sake of keeping contact with interested end-user representatives has been the accessibility of the project management in Umeå via phone and e-mail. End-users have had the opportunity to contact the project at any stage of the project giving direct feedback or just get information about the project.

The continuous feedback to the end-users has also been a way to spread information and knowledge about ICT for assisted living to the population of elderly.

## VI. LESSONS LERNT

The importance of involving the target group at an early stage and to invite them onboard the journey of developing a technical solution designed to fit into their every day life has become clear throughout the project. This generates understanding of the proposed system and of the developing process. It is also appreciated by the end-users to be able to contribute to a possible future even though they may never be able to use the solution by themselves.

Research driven development must respect the targeted end-user and the needs recognized by representatives among the group. It is also important to remember that a target group is a group composed by many different people with different needs and understandings of technology and expectations on life and aiding solutions.

Knowledge and the possibility to give direct feedback to the developers creates engaged and creative meetings with the targeted end-user resulting in unexpected ideas and useful information for the technical partners to start off from.

## ACKNOWLEDGMENT

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# The Specifications of CONFIDENCE: Needs and Demographics of Finnish Older People

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***Abstract***—This paper aims at discovering what the end-users of the CONFIDENCE system might need from ICT system so that their independent and autonomous living is supported by this development. We report the approach and results of a series of structured individual interviews with older people. We also present demographics of Finnish older people.

***Keywords***-older people, needs, CONFIDENCE

## I. INTRODUCTION

Although the use of information and communications technologies (ICT) is spreading rapidly, only a minority of older people are actively engaged in their uptake. This implies that most of the existing Internet-based or online services might not be accessible for older people and hence they cannot be considered very age-friendly technologies. The CONFIDENCE project has adopted a user-centered approach to address the research and development of a Ubiquitous Care System to Support Independent Living in an attempt to close the gap between users and technology. Therefore, the first step in this approach has been to obtain information from end-users about their personal needs in daily living conditions. Other health and social service providers have also been included in this process to add other viewpoints of how CONFIDENCE could contribute to facilitate the independent living of older people in the European Union. The information obtained about end-users needs throughout this process is thus used to derive the technical requirements of CONFIDENCE.

This paper aims at discovering what the end-users of the CONFIDENCE system might need from it so

that their independent and autonomous living is supported by this development. We report the approach and results of a series of structured individual interviews with older people.

## II. METHODOLOGY

The services of the National Research and Development Center for Welfare and Health (STAKES) have been used to collect demographic statistics about the Finnish population, population according to age groups and sex, and statistics about demographical data in the city of Jyväskylä and the rural municipality of Jyväskylä. In particular, the on line SOTKANet database has been used to collect most of these data. This database can be accessed through <http://www.stakes.fi>.

Also, the information services of the Finnish Center for Statistics, i.e., Statistics Finland has been used to access information related to the use of ICT by Finnish users. This information can be accessed through <http://www.stat.fi>.

The end-users questionnaire mainly focused on their needs. As there was not direct background knowledge available about systems comparable to the kind of support system that CONFIDENCE will be, the aim of this approach was to gather the widest range of information possible. With this information, we expect that the technical requirements extracted from it will cover most of the end-users needs.

Each of the end-users was living at home. Three centers were chosen to recruit participants, people visiting the Central Hospital of Central Finland 1-2 times per week for a limited time period or continually, from the Center for Care and Rehabilitation for War Veterans people visiting the center 1-2 times per week, and from the Lutakko day

center, persons visiting the center; e.g. having meal there or visiting or to enjoy social interaction. Seven people participated in the en-users individual interviews. A researcher called to the three centers mentioned and asked if they had customers who could be interviewed. The nurses in these centers chose those who would be suitable in their opinion and asked the participants if they were interested in participating in this research. After that, they called the researcher to provide their telephone number and other contact data. Later on the researcher made individual appointments with them.

The interviews were carried out in the home of the participants because they chose this environment voluntarily when asked where the interview could take place. At the interviewing meeting the researcher introduced herself to the participant and started by creating a good rapport (positive atmosphere) for the interview. Then, the researcher provided information about the project as described in the information sheet. The participants read this information. When a person asked for clarification or additional information, the researcher answered to these and made sure that it had been understood.

Before initiating the interview, the participants read and signed the informed consent form as the CONFIDENCE project has established in its ethical procedures for the research tasks involving human subjects. The interviews lasted approximately 1 h. The information provided about the project as well as the questionnaire and the interview were presented in the Finnish language to ensure that the participants understood the questions.

### III. POPULATION AND SOCIAL AND HEALT CARE SERVICES

At the end of 2007, Finland had a population of 5 300 484 inhabitants. Women over 65 years represent 19% of the population and men over 65 years account for 14%. Table 1 shows that women live longer than men, in the region of Jyväskylä and in the whole country. The figures also show that the population in Jyväskylä and its rural municipality is slightly younger than in the rest of country. A typical phenomenon related to older people's change of residence is that they frequently move from their current place of residence to another place where their children or other relatives also live.

TABLE I. Population in Jyväskylä, i.e., JKL, the rural municipality of Jyväskylä, i.e., Rural JKL, and in Finland according to age group, sex, and general population in 2006 and 2007. Figures for age groups represent percentages; the rows indicating population are absolute values.

Age group	Sex	2006			2007		
		JKL	Rural JKL	JKL	JKL	Rural JKL	Finland
65 and over	male	10.8	10.7	13.6	10.9	10.7	13.7
65 and over	female	16.5	13.4	19.2	16.6	13.5	19.2
65-74	male	6.6	7.2	8.2	6.6	7	8.2
65-74	female	7.9	7.4	9.4	7.8	7.3	9.2
75-84	male	3.4	3.1	4.5	3.5	3.1	4.6
75-84	female	6.3	4.6	7.2	6.4	4.7	7.2
85 and over	male	0.8	0.5	0.9	0.8	0.6	0.9
85 and over	female	2.3	1.4	2.6	2.4	1.5	2.7
Population	male	40338	17733	2583742	40812	18052	2596787
Population	female	44401	17719	2693213	44590	18048	2703697
Total population		84739	35452	5276955	85402	36100	<b>5300484</b>

In Finland, like in most countries in Europe, the Social Insurance Institution of Finland (Kela) manages the provision of pensions for retired people. The legal age for retirement is 65, however, people might be entitled to retire earlier or they

might choose to continue in active working life for longer than 65. This later option has some economical incentives concerning the amount of pension reimbursement the person will receive after retirement. In 2006 Kela spent 1724 million Euros in



old age pensions paid to 477900 beneficiaries over 65 years. Also in 2006, Kela dedicated 217 million Euros to housing allowances for pensioners. In 2006 the average total pension of persons resident in Finland who received a pension was 1194 Euros per month, 1362 Euros for men and 1063 Euros for women. The average total pension of old-age pension recipients was 1246 Euros per month [1].

The organisation and provision of social services is managed by the municipalities. In general, the users pay these services. If their income is not sufficient to cover these costs some reductions or full reimbursement by the social services or Kela can be applied for. The welfare principle is that nobody will be left unattended irrespectively of their income.

As derived from the SOTKANet database in Finland, a new National Framework for High-Quality Care and Services for Older People was issued by the Ministry of Social Affairs and Health and the Association of Finnish Local and Regional Authorities in February 2008. This framework specifies that the national target by 2012 is to attain the following levels for people over 75 years:

- 91-92% live at home independently or with the support of appropriate social and health services granted on the basis of a comprehensive service needs assessment
- 13-14% receive regular home care
- 5-6% receive support for informal care
- 5-6% receive sheltered housing with 24-hour assistance
- 3% receive long-term institutional care in a residential home or health-centre hospital.

At the end of 2006, people over 75 years living at home accounted for 90% of all people over 75 years at the national level excluding those who receive hospital or institutional care or housing services with 24-hour assistance. Of all people over 75, those in regular home care accounted for 12% in 2005. Those people receiving support for informal care for 4%, those in sheltered housing with 24-hour assistance for 4%, and those in long-term institutional care for 7%.

Different municipalities age at different rates. Areas like Helsinki have a relatively young population. At the end of 2006, people over 75 accounted for 8% of the total population in the country. At the municipal level, the lowest shares were only two to three per cent of the total municipal population, while there were also municipalities where 20% of the inhabitants were aged 75 and over. In about twenty municipalities, people older than 75 years, as a share of the total population, are already at the level that the national average is predicted to reach in 2030 [2]. In Jyväskylä there are 8 residential homes for older people provided by non-profit organizations or business enterprises. In the rural municipality of Jyväskylä there are 2 such residential houses.

Most people in Finland leave at home until the age of 85 and later. In Table 2 the condition in which people living in Jyväskylä and the rural municipality of Jyväskylä is summarized. The figures in this table indicate that the situation of the older people in Finland is rather similar to other countries in Europe.

The types of residence in which the older people in the region of Jyväskylä live are defined as follows:

- Home care: Services provided at home based on a care plan, or receive home-help regularly, home-nursing or day hospital.
- Housing services with part-time assistance: A type of sheltered housing in which the client is offered not only accommodation but also other services related to every-day living at least once a week while staff is not available in the unit at night-time.
- Sheltered housing with 24 hour assistance: sheltered housing for older people in which the staff is available 24 hours.
- Residential homes: refers to public and private residential homes for older people and other similar units providing 24-hour care for older people.
- Institutional care and housing services with 24-hour assistance: 24 hour care provided by hospitals, health centres, or sheltered houses with 24 hour assistance. Require the approval of the Social Insurance Institution of Finland.

TABLE II. People living at home, in residential homes, or receiving institutional care as percentage of the total population of the same age, in Jyväskylä (JKL) and in the rural municipality of Jyväskylä (Rural JKL) distinguishing male and female groups in 2006. [2].

Type of residence	2006			
	JKL	JKL	Rural JKL	Rural JKL
	male	female	male	female
Living at home among those aged 75 and over	90.9	88.4	93.9	89.2
Living at home among those aged 75-84	93.9	93.3	94.9	92.9
Living at home among those aged 85 and over	77.8	75.1	87.9	77.3
Residential homes for older people, clients aged 65 and over	1.7	2.4		
Long-term institutional care in residential homes or health centres, clients aged 75 and over	4.3	6	4.2	6.8
Health centres, long-term clients aged 65 and over	0.6	1.1	1.7	3.4

The end-users interviewed in Jyväskylä all lived at home. The size of their homes ranged from 40 m<sup>2</sup> to 129 m<sup>2</sup>. The number of rooms in their house also had a wide range from 1 room and kitchen to 5 and kitchen. In Finland the number of rooms in a house includes the living room, while in other countries the living room might not be considered as a room similar to the bedrooms. Most of them lived close to other family members or friends, and therefore informal care might be expected. The possibility of having people available who can help when problems arise is probably one the major determinants for people being able to live independently until an old age.

#### IV. ICT AND INTERNET

The EU ICT project SeniorWatch (2000-2002) researched on the market potential of ICT products and services for ageing populations in Europe, i.e., people over 50 years. This study revealed that the use of ICT by Finnish older people is more common than for older people on the average in the EU. About 60 % of older Finnish people have used a computer and 35 % Internet in their lifetime. They also lead the European ranking in possession of mobile phones as well as in utilisation of short text messaging (SMS).

According to [3], older people use mobile phones primarily for security reasons. They use Internet for e-mailing, searching information on products and services and for educational purposes. Older Finnish use e-banking services more frequently than in other

EU countries. Also, older people in Finland have a great interest in health information services based on the Internet. However, many Internet applications are still not very well known among older people. For this population group, it can also be difficult to comprehend the benefits that the Internet can offer.

About 40 % of Finnish older people are computer users with professional or advanced skills or use computers at least once a week. Those beginning to use computers at an old age do so less often and have lower skill levels. Those who are technologically oriented and do not use computers, are keen on learning and willing to improve their computing skills [3].

The results of the SeniorWatch project show that about one fifth of older people in Finland and one third in Europe do not use computers and are not interested in learning computer skills. Those people are heavily at risk of being left behind in access in ICT based and digital services that are rapidly becoming common in Europe. In particular, older people from disadvantaged social groups are more likely to suffer the effects of the digital divide.

In Europe 8 % of older people are likely to purchase a computer and 10 % a mobile phone during the next two years. These figures include only those who plan to purchase new equipment. Moreover 10 % is likely to start using the Internet [3].

These figures show that ICT market for older people has a real potential for growth. However, many new older customers will have user requirements that need attention by ICT product and service developers and designers. Restricted ability to see, to hear or to manipulate computer equipment with hands are common conditions among the European older population.

About a half of the respondents in the SeniorWatch study consider that in design of ICT products and services their interests are not taken into account in an adequate manner. Most of the older people also feel that new technologies are always directed towards young people [3]. Accessibility of ICT based devices and services will be a key element in making the information society one in which the design-for-all principle really operates.

The information provided above originates from [3] report of the EU ICT project SeniorWatch. This and other reports from this project can be downloaded from: <http://www.seniorwatch.de>.

Table 3 shows that in the general population the percentage of households in which a personal computer is available have grown 12 % since 2003 until 2006. Internet connections have grown 19 % in the same period. Broad band Internet connections have increased faster probably because these services have become cheaper only in the past few years.

Table 3. Presence of information technology equipment in households as percentage of households in Finland from 2003 to 2006. [2].

Device	2003	2004	2005	2006
Home PC	59	63	66	71
Portable PC	12	16	21	29
Printer	46	48	51	53
Recording CD/DVD drive	.	.	43	51
Internet connection	45	49	57	64
Broadband Internet	16	26	42	55
IP phone subscription	.	.	17	25

The results obtained through interviews with end-users in Finland are in line with these data. Fifteen out of 23 end-users indicated that they do not have problems operating a PC. The same proportion was obtained for the question about problems using the Internet. These results demonstrate a greater proportion of people being able to use ICT among the interviewed people than those in the SeniorWatch project. This might be due to nearly eight years difference in the acquisition of the data in both studies. However the trends are comparably positive. Older people are interested in use ICT. Some of those who do not use ICT are interested in learning computer skills.

## V. END-USERS OPINIONS AND VIEWPOINTS

### A. General background

Individual structured interviews were carried out with 23 people from the city of Jyväskylä. Two experience interviewers presented the participants with the questions. Their age ranged from 48 to 92 years. They all lived at their own homes.

### B. Living conditions and social life

Twelve of the participants cohabited with another partner and 11 lived alone. Most of them lived close to family members or friends and are satisfied with their social life. Only 9 out of the 23 interviewees participated actively in social activities. This result probably indicates that the participants answered strictly according to a very restricted meaning of social activities. Their participation in group gymnastics, and tai-chi group exercise, indicates that other social encounters happen more often than indicated by their categorical (yes/no) answers.

The majority of the participants practice regularly some form of physical exercise. The most commonly mentioned physical activities were: group gymnastics, walking, nordic walking, work out at gym, home gymnastics, gardening, snow shovelling, wood chopping, and cycling. Physical activities are slightly more frequent during summer than during winter time.

Other social activities included the participation in senior clubs, in clubs of the church and other, church related activities, organizational activities, and other clubs.

### *C. Home environment*

Older people houses and apartments in blocks of flats are relatively small. The dispersion in the home sizes of the people interviewed is high. On average the house of the end-users is 70 squared meters. The range was from 32 to 129 square meters. The most frequent number of rooms in the house is 2 and a kitchen. Only 3 participant lived in a studio with only 1 room and kitchen.

Many of the interviewed end-users have obstacles in their home environments including, slippery staircase, stairs outside, some slipperiness in the yard, carpets, spiral stairs, stairs, sharp stairs, slippery hall in winter, hills in the yard, high bench in the sauna, and one step to toilet/bathroom.

Slipperiness, e.g., in the toilet, appears to be quite frequent. Carpets also seem to be quite common obstacles in different countries. Pieces of furniture were not indicated as obstacles in the home environment of the Finnish participants.

### *D. Attitude toward the ICT*

The most frequent expectation about ICT was that this should be simple to use for instance that the systems do not provide too many options. Other expectations included: the price for these should be cheap enough or affordable, that is similar to other technology they are used to or familiar with, expectations about developments which consider their perceptual impairments (i.e., sight, hearing, proprioception).

User instructions should be understandable and in their own language. Electricity consumption and the dependency on electricity might make the systems vulnerable. In general the participants expect that many new developments are still to happen in the future.

The interviewees acknowledged a certain gap between the capabilities of their children and their own in regard to the use of technology, especially the newer ones. They see their descendants as more capable of learning the use of new devices. Each of the end-users was capable of using the TV. Twenty one use a mobile phone, but only 8 out of 23 use a PC and Internet.

Most people have not used other technological devices before. Among the devices used by 7 of the interviewees are: the electronic blood pressure

measurer, the wrist emergency alarm button, automatic functions for bed adjustments, automatic devices to open /close the doors, baby's crying alarm used with grand children, the mobile phone used as an emergency device in the summer cottage.

Out of the 23 people interviewed, 19 demonstrated a positive attitude towards learning to use the CONFIDENCE system, 3 had a negative attitude towards this end, and 1 did not answer. In general respondents would trust the technology in the case of a sudden fall (20), 2 out of 23 could trust the system depending on the situation.

Participants had a positive attitude towards wearing the CONFIDENCE's tags and using the portable device (18) and 1 would accept it as a sort of obligation, and only 1 would not like to wear them. Four end-users would not like to carry a portable device, and 20 would allow mounting a base station at home. The amount of tags to wear would a few as possible, at home the tags should be where they necessary but not interrupting their normal activities and not at the reach of small children.

### *E. Health and functional capacity*

Participants defined their own health mostly as average (13) or good (3), 7 indicated that their health condition is poor. The problems reported by the interviewees were: asthma, back problems, amputation at knee level, constant pain, amputation at hip level, vertigo, heavy medication, recovering from a fracture of tibia and fibula, rheumatism, high blood pressure, myocardial infarct, mildly paralyzed leg, ability to move has got worse, and stroke.

Seventeen had experience dizziness and 12 had fallen during the past 6 months. One person had fallen down at home 25 times, another 15 times. Five people had fallen down outside the house once. The respondents had a variety of medical conditions which could contribute to cause falls, including high blood pressure, eye sight, diabetes, use of prostheses, vertigo, etc.

### *F. Social healthcare services and Informal care*

Thirteen end-users received social services and 10 did not. Typical services received include private cleaning services, laundry, home health care service, taxi tickets, private social service, meal ticket or

meal service. The typical frequency of these services was once or twice a month.

Fourteen participants were satisfied with the social services they receive. Six out of the 23 did not respond.

Informal care was received by 17 interviewees, mostly once or twice a month or once a week. The people providing informal help are usually the children or other relatives.

### G. General expectations

Being continuously monitored by the CONFIDENCE system in the opinion of the end-users could help them feel safer through different psychological and practical mechanisms such as knowing that they are monitored, after one experience of falling and having got help would feel safe, they get help if they are unconscious, the system should be able to provide a warning before actually falling, it would be a relief if one does not need to always think how one can manage in daily life, is it really needed at the age of 92 years? (one respondent), the security alarm button on the wrist is sufficient, cannot say without any experience, if one could contact the helping person by phone, maybe you would not get help from strange people nowadays.

In the case of problematic situations a list of preferences, as stated by the end-users, is provided. This might help with specification of technical requirements for CONFIDENCE:

- There should be 3 buttons from which you would choose the needed help; ambulance, alarm centre, spouse,
- A nurse should come and check the situation
- Automatic call to spouse
- The device would make a sound and an automatic alarm should be sent
- The system should alarm automatically, and you should also be able to press an alarm button yourself
- No intermediate levels in getting help, alarm straight to service that comes to help
- There would be one emergency centre that organises monitoring and help

- Automatic system, someone would come
- Alarm to health care service or relatives, would first ask about the problem and come to help if doesn't get an answer
- Press an emergency button and someone would come to provide help

The end-users indicated that the health care service, the home health care, other public service personnel, or alarm centre, should receive the alarm (12). The public emergency system was indicated by 5 interviewees. Only 2 of the 23 end-users preferred their children as recipients of the alarm.

Nearly 3 out of 4 of the end-users interviewed would prefer to live at home with the assistance of a technological solution. Four of the respondents expressed the importance of the closeness of other people and the quick attention that they would obtain in a sheltered house with 24 hours assistance or similar residence.

### H. Real users' fears

About 50 % of the participants are afraid of falling. However, only 20 % are afraid of going out. Not surprisingly, the condition which more often contributes to a person's feeling of safety is the presence of another person. This other person can be the spouse or partner, or the personnel of a sheltered house.

The main reasons for feeling fearful are health problems, fear of falling, being alone, and not being able to perform one's activities.

#### 1. The level of confidence in CONFIDENCE-like solutions

The end-users indicated the following conditions in which CONFIDENCE could prevent them from falling: that the system might make one move more carefully, could decrease the fear of falling, the tag gets touched and initiates an alarm, it could warn you if you are going to drop off to sleep when you are standing or sitting, if you reach out too far from the bed the system could warn you with a alarm sound, in the future the system may be able to warn you before you actually fall, it could rise your mental state (self confidence), it might help after falling.

Eighteen out of the 23 end-users consider that the system violates the integrity of the user. Some of

their comments deserve attention. These might indicate that the means to an end might justify the use of this technology. The following were comments of some of the end users:

- For a public person it could be a problem
- Not if the information is confidential
- Would violate, if constant monitoring
- Not at this age
- You just have to accept it
- If you have to rely on getting help from somewhere, it doesn't violate integrity

#### *J. Acceptability of CONFIDENCE by the end-users*

At Jyväskylä, we asked the end-users whether they would be willing to use the CONFIDENCE system or not to learn about its acceptability. All of the end-users except one stated that they were willing to use it. The only person who answered no indicated that the reason was that he or she does not need at the moment.

### VI. CONCLUSIONS OF END-USERS OPINIONS AND VIEWPOINTS

The system should work everywhere, inside and outside the home of the users, in the toilet, shower, sauna, in their summer cottages. Some of the summer cottages are in quite unpopulated areas and the telephone networks might not reach there. Also, some of the summer cottages do not have electricity and the power supply of the system should be guaranteed as much as possible.

In Finland older women live longer than men and in the different age groups, women always outnumber men. Taking this into consideration, perhaps, different models for men and women should be designed, e.g., as a watch, jewellery.

The use of global positioning system (GPS) seems to be a good solution. However, more precise systems in terms of positioning accuracy could have greater advantages to locate and find the user by the emergency services. In general the possibility to find a person in need of help quickly is a good advantage.

Allergies or allergenic components of the system should be considered very carefully. In particular allergy to rubber materials should be noted for those

parts of the system which are in direct contact to the skin of the users.

The end-users do not have a great purchase power, in general. The CONFIDENCE system should be durable and affordable.

For very old people and specially those suffering memory problems, the system should not require to be taken off in certain circumstances. Nevertheless, the opinions of the elder and the possibilities to customise or personalise the system according to particular needs of the users should be observed.

The system seems to consider the basic rights of the users in terms of privacy, autonomy, integrity, and dignity. Misuse by others should however be prevented as much as possible. End users consider that their integrity might be affected by a monitoring system. However, when asked to comment on this issue, their qualification somehow softened their answers about integrity as an abstract concept. In cases where burglaries at the home of the users could potentially happen, or the user is afraid of this possibility, the system might include some additional features enabling some sort of security alarm for these situations, or could cooperate with other safety alarm systems the users might have installed in their homes.

Very often, the relatives of the older people are not willing to accept the responsibility for the alarms. Therefore the recipients of the possible alarms could be chosen individually by the user. These recipients could also be changeable because a good recipient at a certain moment might suddenly change his or her status. For instance, a friend might die suddenly, or move to another city, or does not get along with the user anymore.

A specific alarm centre might be a good option as well as the normal 112. The alarm could be directed towards the own home care team from 7:00 to 21:00 h, after that the "night patrol" or 112 could take responsibility of the alarm. The own team is good because they know the person rather well and some people call although there are no relevant problems. They just need to talk to another person.

The alarm modes and protocols should be configurable depending on the people and the circumstances surrounding them. Some examples could include different thresholds for the initiation of the alarm, immediate alarm to the 112 for persons

who are in somewhat known critical health conditions, provide for social contact and not an alarm if the contact is initiated by the user, etc.

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# From User Modeling to Iterative Design and Development: The ÆGIS IP UCD Approach

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**Abstract—** ÆGIS Integrating Project (Open Accessibility Everywhere: Groundwork, Infrastructure, Standards; Grant Agreement: 224348) is a research project, funded by the European Commission in the context of the 7th EU Framework Programme [<http://www.aegis-project.eu>]. It seeks to determine whether 3rd generation access techniques will provide a more accessible, more exploitable and deeply embeddable approach in mainstream Information and Communication Technologies (ICT). This approach is developed and explored with the Open Accessibility Framework (OAF) to be developed in the project, through which aspects of the design, development and deployment of accessible mainstream ICT are addressed. OAF will interface embedded and built-in accessibility solutions, as well as toolkits for developers, for “engraving” accessibility in existing and emerging mass-market ICT-based products, thus making accessibility open, plug & play, personalised & configurable, realistic & applicable in various contexts; ÆGIS is placing users and their needs at the centre of all ICT developments. The ÆGIS target user groups are persons with disabilities (with visual, motor, cognitive and learning, hearing, speech and communication impairments), elderly persons, developers and authors and finally experts (i.e. tutors, production centres, etc.) and other relevant stakeholders. This paper

presents the User Centred Design (UCD) approach developed in the project, focusing on the user modeling phase which has resulted in a set of indicative case studies, Personas and conceptual models, setting in this way the basis for the upcoming development and evaluation phases of the project. The overall evaluation framework developed in ÆGIS for the evaluation of the accessible ICT applications that have been developed in the first 1,5 years of the project is also being presented in short.

*Keywords- open source; accessibility; eInclusion; UCD; user modeling; iterative design and development*

## I. INTRODUCTION

The number of people with disabilities in Europe is estimated to be between 10% and 15% of the total population (between 50 and 75 million people in the EU27), which gives an idea of the number of Europeans at risk of exclusion, as well as the number of potential beneficiaries of accessible Information and Communication Technologies (ICT). Also, the prevalence of both disabilities and other minor functional limitations is strongly related to age. Thus, the already high level of demand for eAccessibility solutions will increase substantially with the ageing of the population. The ageing population in Europe is the most important demographic process in recent years. It is forecast to increase sharply over the coming years due to two main factors: the increase

in life expectancy and falling birth rates. The findings of Labour Force Survey and other surveys indicate that disability increases with age; approximately two-thirds of disabled people are elderly [7].

The ÆGIS IP project (Open Accessibility Everywhere: Groundwork, Infrastructure, Standards; <http://www.aegis-project.eu>) of the 7th European Framework Programme seeks to determine whether 3rd generation access techniques will provide a more accessible, more exploitable and deeply embeddable approach in mainstream Information and Communication Technologies (ICT) [1]. This approach is being developed and explored with the Open Accessibility Framework (OAF) through which aspects of the design, development and deployment of accessible mainstream ICT will be addressed. OAF will constitute a comprehensive, holistic approach to programmatic support for assistive technologies to provide embedded and built-in accessibility solutions, as well as toolkits for developers, for “engraving” accessibility in existing and emerging mass-market ICT-based products, thus making accessibility open, plug and play, personalised and configurable, realistic and applicable in various contexts.

ÆGIS is targeting users with visual, hearing, motion, speech/communication and cognitive impairments, elderly persons (since, as aforementioned, functional impairment increasingly appears in old age), as well as developers of ICT infrastructures, applications and services and relevant stakeholders and groups with interest in design processes (public or private, institutional or community groups) and aims to develop open source based generalised accessibility support into the major mainstream ICT devices/applications domains, namely the desktop applications area, the rich internet applications (RIA), and the Java-based mobile devices domain.

One of the very first activities of ÆGIS was a state of the art undertaken regarding the European AT industry and the availability of past (European) surveys and data regarding the usage of and satisfaction with Assistive Technology (AT) of end users [8]. As shown from this literature survey, AT is widely used, and in many cases has

improved the life of many end-users. However, data seems to indicate that a majority of This work was partially funded by the EC FP7 Integrating Project ÆGIS – Open Accessibility Everywhere: Groundwork, Infrastructure, Standards, Grant Agreement No. 224348. the people with disabilities (people with vision impairments seemingly being an exception) do not use AT, or are simply unaware of existing AT, may lack appropriate training to properly use it and, if they do, are often disappointed with what it offers in relation to what they need. All findings emerging from this survey, like the lack of local language versions of AT or a common policy regarding reimbursement schemes, etc. were cross-checked and confirmed with the findings of the studies undertaken by the project. However, they constitute some first evidence that User Centred Design (UCD) is necessary in the context of AT/AAC prototype development in order to place the end user, user organisations, & support teams at the fulcrum of the overall iterative design and testing process. This is essential for a genuinely iterative approach to AT/AAC design and is being strictly followed within ÆGIS.

This paper presents in short the UCD implementation plan defined and followed in ÆGIS, mostly focusing on its two first phases, which correspond to the “Modeling the user” stage of the project, namely *Phase 1: Gathering user needs* and *Phase 2: Specifying user requirements*, providing in addition some indicative results emerging from each, while presenting also the transpose to the “Iterative Design and Development” stage of the project, encompassing *Phase 3: From Concept to Working Prototype* and *Phase 4: Field Trials*.

## II. ÆGIS USER CENTRED DESIGN (UCD) APPROACH

The UCD implementation plan of the project constitutes the cornerstone of all its phases“ work, starting from the user needs and modeling phases to the iterative design, development and evaluation of the ÆGIS outcomes. Emerging after a thorough literature survey and identification of all applicable methods for each UCD phase, it constituted the basis for the framework for the iterative evaluation of the project outcomes, in three phases and 4 test sites (Belgium, Spain, Sweden and in the UK).

The centric principles followed for the construction of the UCD implementation plan in *ÆGIS*, and is also relevant for all *ÆGIS*-like initiatives, is that (a) active user involvement in the project is not simply at the end, (b) user involvement in this project is a particularly challenging priority due to the extremely diverse nature of the target user audience and the inclusion goal, and (c) everything users see, hear and touch shall be designed together with a multidisciplinary team.

The UCD implementation plan as proposed by *ÆGIS* has four sequential phases. In the first phase, analysis of the users (both end-users with disabilities and developers and experts), their tasks and their contexts are the main focus. Based on these analyses, insight in the problems and needs of the users are collected. Central to phase two is the translation of these problems and needs into a format which can be used throughout the remainder of the project, such as personas, use cases, user scenarios, user requirements, conceptual models, etc. In the third phase, the conceptual models will be developed into prototypes in an iterative, co-design approach. The prototypes of increasing fidelity will be iteratively evaluated with users. In the fourth phase, the final, working prototype which is the result of the previous phase is tested in the field. The four phases are schematically presented in Fig. 1. The interdependencies between the research activities are indicated in the overall context of the iterative process. The four phases are followed for each of the *ÆGIS* application domains (i.e. mobile, desktop, Rich Internet Applications). When possible, the UCD activities will run in parallel for each of these domains, or will even be combined. For instance, in the first phase, the user, task and context analysis have been conducted for each application domain simultaneously.

The first two phases of the UCD plan are the ones that correspond to the overall “Modelling the User” stage of the project, as indicated in the following figure. On the other hand, the third and fourth phases of the UCD plan constitute the “Iterative Design and Development” stage of the project.

It should be mentioned that the applicable for *ÆGIS* UCD techniques in each phase have

emerged from an extensive literature survey held in the early beginning of *ÆGIS* project [7].

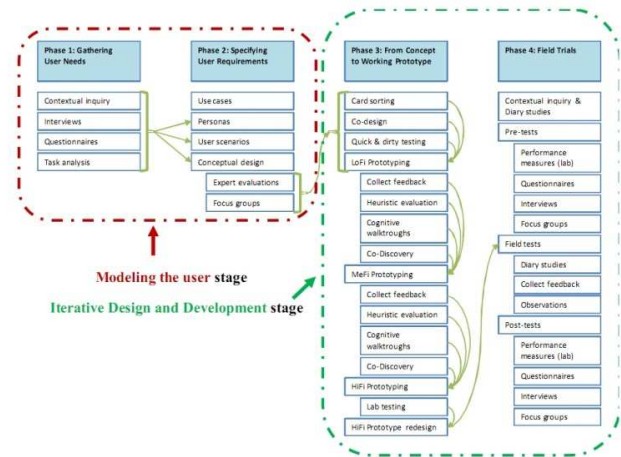


Figure 1. The UCD phases and the interdependencies between the research activities as defined by *ÆGIS* [7].

The UCD *Phase 1: Gathering User Needs* aimed to understand the user, his/her tasks and context, as a necessary prerequisite before moving to design and development of technology and applications for him/her that would be useful, usable and that provide a pleasant user experience. By understanding these factors, insight would be gained in problems that could be solved and in the users’ needs with respect to the topics of *ÆGIS*. Thus, the expected result in this phase was the gathering of deep and rich insights from a substantial panel of users regarding their needs, problems and wants that should be fulfilled within the scope of the *ÆGIS* project.

A combination of quantitative and qualitative methods were being deployed in this phase. On a quantitative level, the user, task and context analysis were done by means of questionnaire surveys that were conducted by phone, e-mail or face-to-face where necessary [8]. The surveys addressed both end users with disabilities and experts for all three areas of the project (the open accessible desktop applications area, the accessible RIA and accessible mobile applications area). On a qualitative level, some of the questionnaire participants were interviewed face-to-face. This was necessary for some users with severe disabilities and it also allowed the discussion of relevant topics on a deeper level as well as a more ethnographic approach in doing contextual

inquiries to observe the users while doing relevant tasks. Based on the observations of participants performing everyday tasks in their personal context, a hierarchical task analysis (HTA) was done, to allow the investigation of existing situations.

The aforementioned field studies were realised in four European countries, namely Belgium, Spain, Sweden & UK and targeted end-users, end-user representatives (e.g. trainers, accessibility assessors), domain experts and developers to gain an in-depth understanding of the context of the use of ICT, i.e. mainstream and assistive technologies (AT) and aimed to uncover all possibilities and challenges that arise when end-users engage with mainstream or AT. A detailed analysis of the results per test site, and herein per application domain, as well as a cross-comparison between the respective sites, also per application domain and per target group, uncovering similarities and differences has emerged and is publicly available through the project web site [1].

Following UCD Phase 1, the UCD *Phase 2: Specifying User Requirements* aimed to translate the insights in the users, their tasks and their contexts, gathered in Phase 1, into system and user requirements. In other words, to translate the succinct ranked list of the major end user, developer, and system requirements, as emerging from Phase 1 to specific Personas, Use Cases and scenarios and conceptual models to enable the realisation of Stage 3 (Phase 3 and 4 in Fig. 1), which aims to interpret, finally, the first concepts to working prototypes and iteratively evaluate them [2]. To verify the relevance and accuracy of all the outcomes, focus group meetings with end users and experts have been organised in the same European countries as the field studies [8], whereas, in addition, 2 Pan-European events were also held [2]. The aim of them was to present preliminary results and ideas in an open discussion format to obtain feedback from individual end-users and stakeholders (developers, end user representative organisations) in an early design phase.

The following Chapters present the major results of the “Modelling the User” stage, as well as the shift to the “Iterative Design and Development” stage of the project.

### III. USER MODELLING STAGE RESULTS

#### A. Use Cases

One of the major results of the UCD Phase 2: Specifying User Requirements have been the Use Cases (UC “s) of the project. The Use Cases, before being reviewed in the context of focus groups and workshops mentioned above, were based on the original technical-wise targets of the three areas of the project (the open accessible desktop applications area, the accessible RIA and accessible mobile applications area) as well as the needs of the target user groups and sub-groups of the project, as identified in UCD Phase 1: Gathering User Needs, emerging from UCD Phase 1 in the form of generic functional requirements [8].

All UC “s have been formulated upon a consistent format, addressing the same major fields namely, context of use (describing the goal of the UC), primary actor (retrieved from ÆGIS User Groups), secondary actor(s) (the interacting persons and/or objects), connected UC “s (referring to other UC “s that each UC is related/linked), priority level (for implementation), which may be essential, secondary or supportive, depending on the of value or primacy for ÆGIS stakeholders as well as on the importance for system operation, background info/reason on selection and on assigning the priority level, scenario(s), describing the task(s) that the user has to accomplish, system output, meaning what should be the system's functionality, as reaction to the user actions/triggering, preconditions, that should be fulfilled for the UC to take place, services involved if applicable, application area (desktop, mobile and/or web), devices and restrictions (PDA, mobile phone, browsers and relevant possible limitations), critical success parameters (thresholds to be taken into account during evaluation), environmental restrictions related to the generic context of use, interaction level, depicting the interaction between the user(s) and the system in subsequent steps, important accessibility attributes (per User Group), related also to critical success parameters, if applicable, relevant Personas, references and comments.

In addition to the textual descriptions of the UC “s, and in order to allow their easy digestion by the

development teams in the future phases of the project, UML (Unified Modeling Language™) diagrams have been developed for each of them, through the StarUML tool [5] and the Enterprise Architect (version 7.1) [6], showing the relationships among actors, sub-modules and activities/actions identified within each UC. The context of use of the UC's developed in the project is described in short below, while, for each the addressed User Groups are indicated, together with their priority level ("essential", "secondary" or "supportive") for the project. Both "essential" and "secondary" Use Cases are the ones that have to be tested in the context of the evaluation activities of the project, while the "supportive" ones will be tested only if the specific UC is not covered/tested through another UC. It is worth highlighting here, that out of the 34 Use Cases developed in total, 12 of which cover the accessible desktop applications, 7 the accessible RIA, and 15 the accessible mobile applications/services area, only 4 of them are considered supportive, whereas the rest of them are all considered essential for the project, and, as such, one should expect their implementation during the development phases of the project, the years to come. Beyond the following clustering, it may happen that a Use Case is applicable for more than one application areas, and this mainly concerns cases, where the background technologies or back-end modules to be developed are common for more than one application areas.

### **Use Cases for Open Accessible Desktop**

#### *1) Screen magnification for the GNOME Desktop*

**Context of use:** The aim is to provide screen magnification functionality for the GNOME Desktop environment that provides both conventional magnification features and more intelligent features built using GNOME's rich underlying accessibility architecture. Current magnification on the Gnome desktop (e.g., GnomeMag) is limited to conventional magnification features and, more importantly, will be obsoleted by changes for Gnome 3.0, including the move to GnomeShell and Dbus.

**Addressed user groups:** Partly sighted (users with a sight impairment and blindness with useful residual vision)

**Priority level for ÆGIS:** Essential

#### *2) Windows screen reader for Java ("Java Access Bridge")*

**Context of use:** The aim is to ensure that Java applications running within Windows environments are as or more accessible by Windows screen readers as native Windows applications.

**Addressed user groups:** Blind (without useful residual vision)

**Priority level for ÆGIS:** Essential

#### *3) Printing Braille in OpenOffice.org*

**Context of use:** A (prototype) "Save as" Braille functionality OpenDocument Text (ODT), OpenDocument Spreadsheet (ODS) and OpenDocument Presentation (ODP) that both individual users and production centres for accessible formats can use when translating documents to Braille.

**Addressed user groups:** Blind (without useful residual vision), persons without disabilities, production centres for accessible document formats.

**Priority level for ÆGIS:** Essential

#### *4) Accessibility Checking for ODF*

**Context of use:** A (prototype) accessibility checker for ODF, especially OpenDocument Text (ODT) that both individual users and production centres for accessible formats can use when saving documents or before exporting to another format.

**Addressed user groups:** Blind (without useful residual vision), persons without disabilities, production centres for accessible document formats.

**Priority level for ÆGIS:** Supportive

#### *5) Full DAISY book creation in OpenOffice.org*

**Context of use:** A (prototype) "Save as" DAISY functionality OpenDocument Text (ODT), OpenDocument Spreadsheet (ODS) and OpenDocument Presentation (ODP) that both individual users and production centres for accessible formats can use when translating documents to DAISY.

**Addressed user groups:** Blind (without useful residual vision), persons without disabilities, slight cognitive limitation and low support need (users with dyslexia/reading impairments), production centres for accessible document formats.

**Priority level for AEGIS:** Essential

6) *Comprehensible multi-lingual documents through a screen reader*

**Context of use:** Automatic switching of the text-to-speech language voice used to match changes in the language used within the document.

**Addressed user groups:** Blind users.

**Priority level for AEGIS:** Supportive

7) *Open interface to Assistive Technologies*

**Context of use:** The aim of this Use Case is to provide interaction between assistive technologies and third party applications that implements the Open Interface.

**Addressed user groups:** Blind users, users with severe or complete restriction on hand use.

**Priority level for AEGIS:** Essential

8) *Gesture switch*

**Context of use:** The aim is to create a gesture switch, detecting a “yes” gesture (such as looking up) from an ordinary digital video stream e.g., from a webcam pointing at the user.

**Addressed user groups:** Motor impairment users (severe or complete restriction in upper limbs; but good vision/eye coordination; “locked-in syndrome)

**Priority level for AEGIS:** Essential

9) *Gaze tracker- “send e-mail with your eyes”*

**Context of use:** The aim is to infer robustly the screen coordinates of a user's gaze from an ordinary digital video stream e.g., from a webcam pointing at the user (this avoids invasive head gear, infrared lighting, expensive high resolution / high framerate cameras, algorithms which make assumptions on the geometry of the eyes, but is thus a much harder problem to solve).

**Addressed user groups:** Motor impairment users (severe or complete restriction in upper limbs; but

good vision/eye coordination; “locked-in syndrome)

**Priority level for AEGIS:** Essential

10) *Graphic Symbol Support for facilitated text comprehension and production in OpenOffice.org*

**Context of use:** The aim is to make the text based environment of a standard Office application suite – OpenOffice.org (OO.org) – accessible as a productive tool also for users with more profound problems in relation to text – both in terms of writing and reading. This will be achieved by – in addition to text-to-speech reading support – providing graphical symbol support. Graphic symbols will illustrate the meaning of the words as they are entered into the text, or when text content is loaded from a file (a freely available open source plugin extension for OO.org.)

**Addressed user groups:** Primarily users with Cognitive Impairments, but also some user with Speech and/or Hearing impairments, as well as some persons with Motor impairment having profound problems with text processing.

**Priority level for AEGIS:** Essential

11) *Integration of open real-time into audio, video, and text-chat desktop applications*

**Context of use:** Enables users to communicate in real-time text, and integrate this solution into exiting audio, video and text chat software to provide a total conversation tool that works in real-time.

**Addressed user groups:** Users with severe limitation or total deafness, users with aphasia (loss of the ability to produce and/or comprehend language) and stuttering and dysarthria (motor speech disorder resulting from neurological injury, characterised by poor articulation). Also, non-disabled users communicating with disabled/elderly people.

**Priority level for AEGIS:** Essential

12) *Generating Accessible PDF from OpenOffice.org*

**Context of use:** The aim is to generate accessible PDF files from OpenOffice.org.

**Addressed user groups:** Blind users, any users interacting with persons with visual impairments.

**Priority level for ÆGIS:** Essential

**Use Cases for Accessible Mobile Applications Area**

*13) Accessible Mobile Phone for the blind*

**Context of use:** A mobile phone research platform, together with a freely available open source screen reader for the blind, providing for an accessible mobile phone experience.

**Addressed user groups:** Blind and low-vision users

**Priority level for ÆGIS:** Essential

*14) Mobile as an Augmentative and Alternative Communication (AAC) device for severe motor and/or speech impairments.*

**Context of use:** The aim is to make the environment of a standard mobile phone accessible as a productive tool for users with profound motor problems (including switch users) – both in terms of writing and reading SMS/IM and operating the phone for making voice calls and navigating and controlling major phone functions. Text-to-speech (TTS) will provide reading support and may also act as the user's voice when making calls. Graphic symbols / photographic images (using the CCG) may be used to illustrate the meaning of messages and menu items as they are presented, or when text content predicted. Configurable traditional or T9 style on-screen keyboard (OSK) with word prediction, alternatively mobile “Dasher” input, to be used by a direct selection or switch user to send and receive SMS/IM. etc.

**Addressed user groups:** Primarily users with motor impairments (including switch users), speech and cognitive impairments, who have profound problems with text processing.

**Priority level for ÆGIS:** Essential

*15) Symbol-based Augmentative and Alternative Communication (AAC) system for mobile devices for direct person-to-person (face-to-face) communication*

**Context of use:** The aim is to make it possible for a person with a speech and communication impairment to communicate directly with another person by using a mobile device as a VOCA

(Voice Output Communication Aid) – with or without the support of the graphical symbol/text display.

**Addressed user groups:** Primarily users with speech, and/or cognitive, and/or motor impairments.

**Priority level for ÆGIS:** Essential

*16) Augmentative and Alternative Communication (AAC) for instant and text messaging (IM/SMS) on mobile devices*

**Context of use:** The aim is to make an accessible instant messaging on mobile phones through AAC (supported by voice and text). Graphic symbols – based on the Concept Coding Framework (CCF) – will illustrate the meaning of the words as they are entered into the message.

**Addressed user groups:** Primarily users with cognitive Impairments, users with speech and hearing impairments, users with motor impairments having profound problems with text processing.

**Priority level for ÆGIS:** Essential

*17) Onscreen keyboard for motor impaired operation of a mobile*

**Context of use:** The aim is to provide motor-impaired individuals, with severe motor-impairments and very limited mobility (e.g., 1 or 2 input actions) with the ability to navigate and operate mobile device user interfaces and enter text.

**Addressed user groups:** Users with severe or complete restriction on hand use.

**Priority level for ÆGIS:** Essential

*18) Rapid text entry into a mobile device*

**Context of use:** The aim is to create a rapid text input method for a mobile device which doesn't require the frequent and accurate pressing of at least one button per letter.

**Addressed user groups:** Users with slight dexterity difficulties (motor impairments), and especially when coupled with text-to-speech and users with stuttering and dysarthria.

**Priority level for ÆGIS:** Essential

*19) Captions for the deaf display in mobile video*

**Context of use:** Deaf user enjoying movies/videos on their mobile device because they contain (and correctly display) captions.

**Addressed user groups:** Users with severe limitation in hearing or total deafness.

**Priority level for ÆGIS:** Essential

*20) Audio description for the blind/low-vision played in mobile video*

**Context of use:** Blind or low-vision user enjoying movies/videos on their mobile device because they contain (and correctly play) video descriptions.

**Addressed user groups:** Blind and low-vision users.

**Priority level for ÆGIS:** Essential

*21) Real-Time Text for mobile devices*

**Context of use:** Enables users to communicate in real-time text through their mobile phones.

**Addressed user groups:** Users with severe limitation or total deafness, users with aphasia (loss of the ability to produce and/or comprehend language) and stuttering and dysarthria (motor speech disorder resulting from neurological injury, characterised by poor articulation). Also, non-disabled users communicating with disabled/elderly people.

**Priority level for ÆGIS:** Essential

*22) Accessible messaging application for mobile devices*

**Context of use:** Most mobile communication devices include one or more messaging applications – encompassing SMS, MMS, e-mail, and IM. This application integrates all these text technologies (adding real-time text) in a single accessible solution that makes text communication accessible for all.

**Addressed user groups:** Users with a sight impairment and blindness with useful residual vision and blind users, users with dexterity difficulties or slight, moderate, severe or complete restriction on arms or hands, users with slight, moderate or severe cognitive limitation and low,

medium or high need for support, hearing impairment users (of any severity level up to total deafness), users with aphasia, stuttering and dysarthria as well as non-disabled users communicating with disabled/elderly people.

**Priority level for ÆGIS:** Essential

*23) Accessible phone dialer and contact manager for mobile devices*

**Context of use:** Every mobile phone includes several core applications. If these applications aren't accessible, then fundamentally the phone isn't accessible. The two core applications are the phone dialer, and the address book/contact manager that should be always accessible to people with disabilities via assistive technologies.

**Addressed user groups:** Partly sighted and blind users, users with dexterity difficulties or slight, moderate, severe or complete restriction on arms or hands, users with slight, moderate or severe cognitive limitation and low, medium or high need for support, users with slight or moderate hearing impairment and users suffering from aphasia, stuttering and dysarthria.

**Priority level for ÆGIS:** Essential

*24) Assistive technologies for mobile devices toolkit*

**Context of use:** Using the ÆGIS developer tools and support libraries for creating an assistive technology for people with disabilities to use on their mobile device.

**Addressed user groups:** AT developers

**Priority level for ÆGIS:** Supportive

*25) Accessible applications for mobile devices toolkit*

**Context of use:** Using the ÆGIS developer tools & UI component sets to build accessible applications for Java-based mobile devices.

**Addressed user groups:** Mainstream application software developers and experts and mobile application developers.

**Priority level for ÆGIS:** Supportive

*26) Mobile application developer developing accessible Java FX applications for mobile devices*



**Context of use:** Java FX mobile application developer develops a highly accessible Java FX mobile application.

**Addressed user groups:** Mobile content/application developers and mainstream mobile application developers/experts.

**Priority level for ÆGIS:** Essential

27) *Developing accessible mobile s/w*

**Context of use:** To prototype approaches to making mobile application user interface component sets accessible to people with disabilities.

**Addressed user groups:** Mobile applications developers, Graphical User Interface designers, s/w designers and analysts.

**Priority level for ÆGIS:** Essential

### Use Cases for Accessible Rich Internet Applications (ARIA) Area

28) *Web developer developing accessible DHTML RIA application*

**Context of use:** A DHTML RIA developer develops a highly accessible rich-internet application, using ÆGIS toolkit(s).

**Addressed user groups:** Web content/application developers.

**Priority level for ÆGIS:** Essential

29) *Web developer developing accessible Java-based RIA application*

**Context of use:** A Java-based RIA developer develops a highly accessible rich-internet application, using ÆGIS toolkit(s).

**Addressed user groups:** Web content/application developers and mainstream application software developers and experts. Priority level for ÆGIS: Essential

30) *Visually impaired user using Java-based RIA application*

**Context of use:** Visually impaired user (also blind) tries to access a Java-based RIA application to proceed his/her task. The RIA application is developed using ÆGIS toolkits and thus accessible with help of ATs used by the user.

**Addressed user groups:** Blind or low vision users.

**Priority level for ÆGIS:** Essential

31) *Using an internet map: visual adaptation*

**Context of use:** The aim is to provide an Internet map application for users with low vision. The Internet map application should be easily accessible for users with low vision. This means that the map can be read and understood easily, and that users are able to manipulate the map, and use it for localisation and navigation.

**Addressed user groups:** Partly sighted.

**Priority level for ÆGIS:** Essential

32) *Accessible Rich Internet map Applications using the OCR (Optical Character Recognition) and VRML (Virtual Reality Modeling Language) technology*

**Context of use:** The aim is to provide the visually impaired with an easy to use means of accessing conventional 2D maps. The user can interact with the produced 3D model of the map and examine its properties. The developed framework analyzes the map image so as to obtain the enclosed information. While navigating, audio messages are displayed providing information about the current position of the user (e.g. Street name, cross-road notification and so on).

**Addressed user groups:** Blind and low vision users.

**Priority level for ÆGIS:** Essential

33) *ARIA support in browser*

**Context of use:** The aim is to ensure that there is browser support for W3C-WAI's developing ARIA (Accessible Rich Internet Applications) technology.

**Addressed user groups:** Blind users.

**Priority level for ÆGIS:** Essential

34) *Applying WAI-ARIA to open-source CMS widgets*

**Context of use:** The aim is to enhance CMS's widget accessibility through the application of the WAI-ARIA roles, states and properties in order to produce a CMS demonstrator, which would show

how a Web author could use the provided framework and thus produce accessible blogs without the need for doing programming themselves. End-users of screen readers will perceive these blogs as accessible.

**Addressed user groups:** Blind and low vision users.

**Priority level for ÆGIS:** Essential

### B. Personas

In addition to the Use Cases of the project, another major result of UCD Phase 2: Specifying User Requirements have been the Personas of the project.

The methodology adopted for the Use Cases development is supported by a theoretical approach based upon the Action and Activity Theories, a research on Use Cases revealing the need of defining a Problem-domain (i.e. Use Cases context) and a Model-domain (i.e., common terminology) as well as the UML diagrams to represent the Use Cases. Still, the main principle behind Problem-domain and Model-domain is that Use Cases themselves do not capture important information on the surrounding context. So, the problem-domain (i.e., the context, the environmental aspects) should be first analysed and described. For this purpose, the Personas work run almost in parallel with the Use Cases work in ÆGIS and was completed much before the finalisation of the Use Cases, setting in this way a common reference and terminology for the Use Cases that will serve to support the ÆGIS developments.

Thus, Personas actual target in ÆGIS has been to address exactly this problem-domain aspect and this was achieved by interpreting the collected user needs info (emerging from the field trials and workshops) to fictitious archetypes of real users (featuring specific user characteristics, problems, needs and wishes, and not general ones representing the “average user”), constituting in this way the most efficient possible design and context of use capturing tool, considered very essential for the developers, and also very innovative in comparison to a theoretical consolidation of descriptive info that could be held

instead. Personas are public and can be found in the project web site of ÆGIS [1]. The following table presents the personas developed for each end-user group, targeted by the project. As in real people with disabilities, some of the personas (Emma, Jane, Peter and Wayne) have multiple impairments; thus, the names of these personas are mentioned in each relevant end-user group.

TABLE 1. ÆGIS PERSONAS-USER GROUPS MAPPING

ÆGIS Personas	
ÆGIS targeted end-user group	Relevant Personas
Visual impairments	Gert, Märta, Nitesh, Paulina
Motor impairments	Caroline, Jane, Mikel, Peter, Ramin
Cognitive impairments or learning difficulties	Adam, Peter, Wayne
Hearing impairments	Edward, Emma, Tomasa
Speech/communication impairments	Carlos, Emma, Jane, Wayne
Experts	Benoit
Developers	Clyde

Each Persona is introduced with a name, a picture and a short description of his personal situation. This includes age, marital status, education, job and a short description of the persona’s impairment. In addition, each persona describes which technologies s/he uses in everyday life, and for which purposes. In the case of users with a limitation, the adaptive strategies for using a product are also described here, such as special tools or assistive technology (for example „uses screen reader software”), experience and skills with these tools or assistive technologies, and the frequency of use of the tools and technologies. Furthermore, a list of problems in using the technology in itself or in using the assistive technology is provided. Based on these problems, a section of each persona is dedicated to the overview of his/her needs and wants. The problems, needs and wants in using technology and special (assistive) tools are illustrated more concretely in a short description of a current scenario out of the life of the Persona. This section (titled “last month ...”) describes an everyday incident or event in which the persona was confronted with a particular problem or need. In this way, ÆGIS has achieved to interpret all collected user needs in an absolutely meaningful

and valuable format for further use, which is in parallel very easy to link with the project Use Cases.

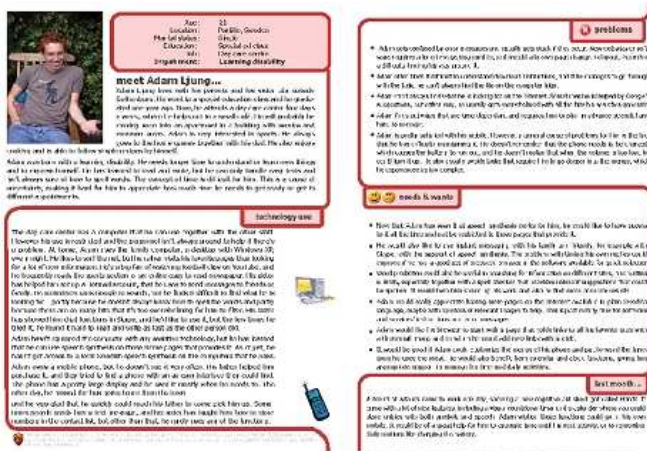


Figure 2. Example of Persona (Adam Ljung).

The final step in this process has been the formulation of some condense use scenarios, on the basis of the above Use Cases, which have constituted the basis for the detailed and more specific evaluation scenarios that will orient the evaluation activities of the project. Three major application scenarios have emerged, consisting of sub-scenarios, whereas the relevant user profile (linked to the relevant Persona) is also described in each case.

C. Conceptual Models

Finally, as explained in the UCD plan of ÆGIS, the creation of the conceptual models is a central step in the phase of specifying user requirements. A conceptual model represents a high-level structure for the system. The concepts and the entities that form the system are described in the conceptual design. Many possible formats for conceptual models are used, but these formats all have in common a description of the system from a user point-of-view. These models answer questions such as „which services and features does the system offer?“, how does the user interact with the services and features?“, etc.

On the basis of the UCD Phase 1 outcomes and taking into account the Use Cases, Personas and user scenarios of Phase 2, a conceptual model has been developed for each ÆGIS identified prototype (priority is given to those expected to be evaluated in the first evaluation phase), reflecting,

the functional requirements of the upcoming prototypes, after cross-checked with the user insights [2]. An example of the 13 conceptual models developed in ÆGIS is provided in Fig. 2.

Symbol support in OpenOffice.org	
Relevant use cases:	Graphic Symbol Support for facilitated text comprehension and production in OpenOffice.org
Relevant personas:	Jane Brown (speech/communication impairments), Wayne Edwards (cognitive impairments), Adam Ljung (cognitive impairments)
Functionality	<p>The prototype will be a plugin extension to OpenOffice.org that adds graphical symbol support to text files. More concretely, the graphical symbols illustrate the meaning of the words as they are entered into the text, or when text content is loaded from a file. This allows the user to:</p> <ul style="list-style-type: none"> <li>produce text with some degree of graphical symbol support,</li> <li>open a document and access and comprehend unknown text content with the support of graphical symbols,</li> <li>manage the document content: change display mode, save, print ...</li> </ul>
Interaction	<p>The user wants to produce symbol (and speech) supported text, be able to access and comprehend unknown text content with the support of graphical symbols (and speech), and manage the document content – editing, saving, printing. The following activities/tasks are involved in producing and comprehending text:</p> <ul style="list-style-type: none"> <li>The user can enter standard text into the system character by character. Afterwards, the user can select a word from the text and request a symbol look-up. The system looks up the concept(s) matching the word and displays the corresponding graphical symbol.</li> <li>The system can also display matching concepts and graphical symbols after each word.</li> <li>The user can also enter text into the system by selecting words or phrases on a word symbol chart.</li> <li>The user can also open and read an existing file, and save it via a Save or Save as command. Files are saved with the graphical annotations.</li> <li>Displaying and printing a file is also possible: as a document with text and symbols, as a standard text document, or with an alternative text representation.</li> </ul>
User	<p>User groups</p> <ul style="list-style-type: none"> <li>3. Primarily users with Cognitive Impairments,</li> <li>5. Users with Speech and/or Hearing impairments,</li> <li>2. Users with Motor impairment having profound problems with text processing</li> </ul> <p>Extra requirements</p> <p>For users with a cognitive or speech impairment, access to good integrated text-to-speech support, as well as alternative phrase/word symbol based input is required. For users with a motor impairment, access to alternative text input support is required.</p>

Figure 3. Example of Persona (Adam Ljung).

IV. EVALUATION AS PART OF ITERATIVE DESIGN AND DEVELOPMENT STAGE OF ÆGIS

All tangible results of UCD Phases 1 and 2, encompassing the ÆGIS Use Cases, Personas, application scenarios and conceptual models, have constituted the basis for the specific application scenarios and experimental plans that have oriented the evaluation of the 10 first prototypes of ÆGIS in the first round of evaluation, that took place from May 2010 until end of July 2010. This has been only the first of the three evaluation rounds that are scheduled in the project in the context of the iterative design and development character. This section describes in short the overall evaluation framework developed in ÆGIS, focusing on the first out of the three in total evaluation rounds scheduled in its context.

A. The Iterative Evaluation Framework

ÆGIS has developed a horizontal evaluation plan involving several sequential iterative heuristic evaluations that shall involve both experts and users, as appropriate, at various stages of the development lifecycle of all the proposed prototypes and applications. Sequential evaluations involve a series of evaluation techniques that run in sequence, such as contextual inquiry, naturalistic observations, performance testing, technical validation on the hand, etc. [4].



As currently identified, the applicable evaluation categories of ÆGIS are namely the technical validation, conducted by the developers, the Human Factor assessment, enabled through the participation of end-users and several types of experts, whereas socio-economic assessment and impact assessment will be performed off-line, utilising feedback by the three evaluation rounds. The high-level objectives of the four targeted evaluation types are presented in TABLE II below.

TABLE II. FIRST EVALUATION PHASE TECHNIQUES AND TOOLS TO BE APPLIED-HUMAN FACTOR ASSESSMENT.

ÆGIS Personas		
Category of evaluation	Main evaluation objectives	User Groups involved in Validation
<b>Technical validation of application</b>	Validation of expected system performance -Quality of Service & Accessibility aspects	All types of developers applicable for each type of solution
<b>Human Factors Assessment</b>	<ul style="list-style-type: none"> <li>System usability (embedding accessibility as an inherent scope in ÆGIS case)</li> <li>System acceptance</li> <li>Effects on users' self-confidence and Quality of Life</li> </ul>	<ul style="list-style-type: none"> <li>E&amp;D users</li> <li>Developers (if applications are made for developers)</li> <li>Focus groups experts (potentially)</li> </ul>
<b>Impact analysis</b>	<ul style="list-style-type: none"> <li>Satisfaction and QoL of E&amp;D</li> <li>Mobility/ employability of E&amp;D users</li> <li>New business opportunities in the rehabilitation sector</li> <li>Market penetration of eInclusion Services</li> <li>More to be defined during the progress of the project.</li> </ul>	<ul style="list-style-type: none"> <li>Indirect - Experts will analyse the data fed by the Pilots)</li> </ul>
<b>Financial and socio-economic evaluation</b>	<ul style="list-style-type: none"> <li>Willingness to Have (WTH)</li> <li>Willingness to Pay (WTP)</li> <li>Detection of ÆGIS applications strengths and weaknesses in comparison to existing solutions.</li> </ul>	<ul style="list-style-type: none"> <li>Elderly and Disabled users</li> <li>Indirect - Experts will analyse the data fed by the Pilots)</li> </ul>

Having as starting point the results of the first two UCD phases, as aforementioned, an investigation has been held, of all applicable for ÆGIS evaluation techniques, approaches and tools. As such the most relevant to the specific

prototypes of the 1st evaluation phase, techniques and tools, both conventional and novel, have been identified in the context of the validation plans of the first phase and are summarized in TABLE III below.

TABLE III. FIRST EVALUATION PHASE TECHNIQUES AND TOOLS TO BE APPLIED-HUMAN FACTOR ASSESSMENT.

ÆGIS Personas	
Evaluation technique	Tools to be used
Training workshops and consent forms	Consent forms and training manuals
Questionnaires/Interviews	<b>Subjective:</b> Pre-test form
Performance testing combined with Naturalistic Observations and Contextual Inquiry	<b>Objective:</b> Service diaries and video/sound/screen recordings, in combination with: <b>Subjective:</b> Think Aloud/Co-Discovery Protocol/open questions
Questionnaires/Interviews	<b>Subjective:</b> Post-test forms, including standard scales and prototype-specific questions
Focus Groups	<b>Subjective:</b> Open questions and free discussion and questionnaire

The evaluation approach followed in ÆGIS needed to encompass all types of users that are interfering directly or indirectly with its solutions. Therefore, as shown in TABLE III above, besides performance testing with end-users, deploying naturalistic observation methods, focus groups have been planned in order to involve tutors, experts and other relevant stakeholders.

Furthermore, ÆGIS will try to gather both subjective and objective measurements; not aiming to evaluate the users' performance; on the contrary for evaluating the systems' performance through users' interaction with them. Therefore, on the basis of the initial project Use Cases, Personas, application scenarios and conceptual models of "Modelling the User" stage of the project, specific tasks have been defined for the interaction of the users with the prototypes during the first evaluation phase (and this will be the case for the next evaluation phases as well), during which the tests supervisors, through service diaries will

monitor the users' interaction and keep notes on pre-defined measures but also free notes. The video/sound/screen recording sessions that will be planned whenever possible (and allowed by the participants) will also support the in-depth analyses of the users' performance with the prototypes.

On the other hand, the developers themselves, in the context of the technical validation, will also measure (to the extent enabled by the maturity of the prototypes) their systems' performance and their results will be compared and consolidated, when similar, to the user trials' results. However, it should be noted that all aforementioned will be better performed in the second and third evaluation round of the project (although planned also for the first one and partially executed). The improved fidelity of the prototypes (and those to be added) then will enable the incorporation of more sophisticated measurements and tools for them and, as such, more valuable results.

In parallel, the approach to be followed for the participants' recruitment had been defined from the early beginning of the project, on the basis of selection criteria dealing with subjects' age, type and severity of impairment, gender, Assistive Technology and Accessibility Solutions acquaintance and previous experience, in order to meet the desired equilibrium. From the early beginning of ÆGIS, it has been decided to engage in the greatest possible extent the same users across all evaluation rounds and studies; thus, it has been anticipated that a portion of the users and experts participating in the field trials of the first year will be engaged as much as possible in all the evaluation rounds to follow; and this was the case for the first round already executed.

In the context of the first evaluation round, 10 prototypes have been tested with users and some of them also underwent a technical validation.

The 10 prototypes have been evaluated with 316 users with impairments, 8 production centres representatives, 14 RIA developers, 164 tutors, 14 evaluators and 155 experts in total, across 6 test sites (and 4 countries), namely in Belgium by EPR and KUL, in Spain by FONCE, in Sweden by SU-DART and in the UK by ACE and RNIB.

The test sites aforementioned were responsible for conducting user trials, in the context of the Human Factor Assessment. On the other hand, technical validation was also conducted on the developers' sites (those that have developed that prototypes to be tested also in the user trials) for the most mature prototypes.

The iterative nature of testing will be one of the core concepts that will be maintained throughout the project. More specifically, ÆGIS is committed to build user-based and technical validation into all stages of the development lifecycle, from the very first prototypes until the pre-release stage; this is the major reason for scheduling 3 evaluation rounds and one final demonstration phase in the context of the project. The evaluation outcomes will provide valuable feedback to various design and development teams of the project, whereas the experience to be gained by a number of spread evaluation groups will be consolidated and documented appropriately in order to serve as reliable, yet raw, input to standards and exploitation plans.

Last but not least, an important aspect of the ÆGIS research and development activities, and, more specifically, of the evaluation activities to be conducted is the monitoring of compliance to the project's ethics policy concerning them. An Ethics Policy has been established in ÆGIS, according to which, evaluation, among other activities, should be fully compliant. Local Ethics Committees have been formulated locally in each test site to apply the Ethics Manual developed and monitor the trials adherence to that [3]. Part of the Ethics Policy developed in the project was the instantiated consent forms and processes formulated for each type of impairment user groups.

### *B. The First Prototypes Evaluated*

During the first 12-16 months of the ÆGIS project, there have been 6 preliminary prototypes developed by the respective development teams in ÆGIS, which reached an adequate maturity level in order to be included in the first evaluation phase of ÆGIS. These are the namely the "Accessible Contact Manager and Phone Dialer", the "Concept Coding Framework Ooo Symbols" (CCF Symbol Support plug-in for OpenOffice.org Writer), the "DAISY Production", the "GnomeShell

Magnifier”, the “Haptic RIA maps” and the “ÆGIS RIA Developer tool”.

In addition to the above prototypes, there were 4 concepts/prototypes selected to be tested in addition in the context of ÆGIS, without constituting actually ÆGIS prototype. The reason for this is either because they are considered as basis for future relevant ÆGIS implementation, and as such, their evaluation is very critical to ÆGIS in order to be decided if the project should comply or not with them and to which extent or because their testing practically constitutes the first step of further development (as it is the case for Text To Speech sample files evaluation). These are namely the “Open Speech Access to the GNOME Desktop environment” by Sun, the “AIM Real-Time Instant Messenger” by AOL, the “Oratio for Blackberry” by RIM and, finally, a collection of some Text To Speech sample files for language evaluation.

## V. CONCLUSIONS AND NEXT STEPS

The outcomes of the “Modelling the Use” stage of the project have been presented per test site in the context of focus groups and workshops and showed that the end user and development community is keen on embracing ÆGIS, under the condition it remains an "open project" and considers the needs of end users. This implies applying the UCD approach throughout the project as well as involving development communities and organisations that promote open software, offering access to source code and publishing information throughout the entire course.

The major results of the two first UCD phases of ÆGIS is the thorough understanding of the targeted users, their needs and wants, which in turn have formulated the basis for the user requirements work of the project, which has been materialised in elaborate Use Cases and user scenarios, Personas and conceptual models, that will constitute the groundwork for the iterative design and prototyping phases of the project.

The further steps in the context of the “Iterative Design and Development” stage of ÆGIS, introduced in short in this paper, focusing on the evaluation framework established and the plans of the first evaluation round, already executed, are the consolidation of all test results, the emerging

of guidelines for the project developers in order to assist them with the optimisation phase until the next evaluation round and the emerging of any recommendations and feedback for standards in the area. Finally, based on this first experience, the ÆGIS Consortium will learn and optimise the procedure to be followed in the next evaluation phases across all aspects and, incorporate, whenever possible, more novel tools for more objective performance measurement with ÆGIS applications.

Above all, ÆGIS aims to constitute a useful guide and reference for the on-going evolution of the eInclusion and eAccessibility areas as well as the Open Source Community across all interrelated aspects of modeling, design and development and evaluation. In specific, the UCD approach as being defined and adopted by ÆGIS project, may serve as a valuable practice for similar initiatives that need to be user-centric in order to achieve usable, useful and easy to penetrate products in the eInclusion field and beyond.

Finally, it should be noted that all core outcomes mentioned and shortly described in this paper, are public and can be downloaded from the project web site (<http://www.aegis-project.eu>), while are all considered working documents that may undergo several updates and revisions, following the progress of the project as well as the evolution noticed in the open source accessibility community.

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# The ACCESSIBLE Software Applications Accessibility Assessment Tools and Evaluation Framework

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**Abstract**—Accessibility today is gaining more and more ground, becoming a real necessity in daily living and every day needs. Authorities and experts are putting a lot of effort towards accessibility, especially in the software application domain. Despite this fact the ICT applications and systems are still not fully accessible.

The main idea of the ACCESSIBLE project is to contribute towards better accessibility for all citizens. This will be achieved by increasing the use of standards and by the development of an assessment simulation environment, as well as, a harmonized methodology that links all accessibility components.

The scope is to enhance the ICT products accessibility in all applications in a broader field, by enabling large organization, SMEs or individuals to produce accessible software products.

In the current paper we will introduce the reader in the general scope and results of ACCESSIBLE project through the presentation of the basic outcomes. Attention will be given to the evaluation methodology and plans of the ACCESSIBLE outcomes assessment, as well as, the Use Cases of the project, which illustrate the usability and the utility of the ACCESSIBLE tools.

**Keywords-** *accessibility assessment; eInclusion; UCD, evaluation, ICT.*

## I. INTRODUCTION

The potential for the software development products to improve people's lives and raise their standard of living is enormous. People with special needs, including impaired motor skills, weak visual acuity, and cognitive and learning disabilities, are a large and growing community with increasing interest in technology. They constitute a large percentage of the on-line community (approximately 10%), with the numbers expected to grow as the online services improve. Disable community is an under-serviced market that demands the same opportunities for Web access as everyone else.

The World Wide Web provides a wealth of information, for the diverse user's population of the web, including users of all ages, educational levels, and levels of computing experience [1]. It provides opportunities to participate in society in ways otherwise not available. The goal of Web accessibility is to permit the maximum amount of people to enter and use each Web site. Some Web accessibility issues for the disabled community may include one or more of the following:

- Inability to see, some or all of the information.
- Inability to hear, some or all of the information.
- Inability to read, understand or process, some or all of the information.
- Inability to use a mouse due to mobility limitations.

Accessibility and ease of use for the elderly and the disabled has attracted a lot of attention during the last few years. This is strongly supported by the fact that an increasing number of governments are

legislating towards promoting and enforcing equality of opportunity and of access for everyone within the economy and society (Inclusion) [2], including in terms of access to ICT and the evolving Information Society (eAccessibility) [3].

Soon after the appearance and early developments of assistive technology, such as screen readers, special interaction devices, etc., researchers and practitioners realised that access to a computer-based system is often denied to large numbers of potential users as a result of the system's design. In the old days, it was widely believed that the interaction ability of an individual is simply subject to his/her functional characteristics. Yet, we now understand that it is the design of system in combination with the functional characteristics of the user that renders the person able or unable to interact with it.

Accessibility is not just a high-level theoretical goal. Currently, there are guidelines that web developers can follow so that their web sites can be accessible. For instance, the Web Accessibility Initiative (WAI) provides guidelines, called the Web Content Accessibility Guidelines (WCAG), to help developers make their web sites accessible. The United States Government offers similar guidelines to web developers, which are included in the Section 508 initiative. In addition, automated software tools have been developed, that are available to help the developers find accessibility flaws in web sites before the sites are publicly posted [4]. These software tools include RAMP, A-checker, WebAim etc.

Unfortunately, it is a fact that the majority of software development products and Web based information, facilities and services is unnecessarily inaccessible to people with certain disabilities, largely due to a lack of awareness of accessibility issues on the part of developers. Recent studies point out that large percentages (70–98%, depending on the category of site) of web sites are not accessible. Most websites have accessibility barriers that make it difficult or impossible for many people with disabilities to use them. And most web software tools are not sufficiently accessible to people with disabilities, making it difficult or impossible for them to contribute to the Web. Web accessibility is about removing those barriers so that people with disabilities can use and contribute to the Web.

In general, the vast majority of developers today, by "tradition" (if not as a compromise), insist on designing their artefacts for the typical or so-called "average" users, trusting this as the best solution to cater the needs of the broadest possible population. These are most probably the leftovers of last century's anthropometry and the important role it played in industrial design, clothing design, ergonomics, and architecture, where statistical data about the distribution of body dimensions in the population were used to optimize products. Unfortunately, this approach when ported into the design of ICT, it eliminates our chances offered by the new medium (digital) to provide more flexible optimisations. In fact, this approach, typically employed in user interface design for quite some years, leads into excluding numerous "outliers", such as non-expert IT users, the very young or the elderly, people with disability, etc. [[5], [6]]. As computers started to penetrate all aspects of our everyday lives, and becoming a critical asset for social inclusion, developers are eventually pushed by social or market needs towards broadening their user base, are often required to further "improve" their artefacts so that these adhere to generalised (i.e., average - again) usability and accessibility principles.

Clearly, there is now a vast amount of knowledge available in the international literature concerning inclusive user interface design. Knowledge that is incarnated in guideline sets, standards, corporate guides, etc. Knowledge that is generic or specific, for example for the elderly, or for web or mobile interfaces, etc. As a result, developers are finding it difficult to locate and deploy effectively such knowledge in their development process. For instance, a web developer with no prior experience in web accessibility engineering would find it extremely difficult to identify the differences between the WCAG 1.0, 2.0 and the Section 508 guidelines, would be uncertain about the actual types of users affected by each particular guideline, and would be confused, the least to say, by most of the checkpoints entailed. What happens if the developer would like to provide two alternative designs for the same task in order to cope with conflicting needs of two user types? Not to mention that contemporary users increasingly desire and expect the delivery of interfaces that are highly tailored to their own needs, and hardly compromise on rigid designs for some

imaginary "average" users. In such cases, how can an inexperienced developer identify which guidelines are most appropriate for each one of the alternative design? All these questions make clear the need for the envisioned methodology for harmonising design knowledge and rendering it easy to understand and apply for modern ICT designers and developers.

Thus, the development of software requires specialised expertise and a strong effort from developers. With the additional encumbrance of taking into account different kinds of accessibility requirements, guidelines and best practices, and different implementation technologies (which by themselves might pose severe problems of delivering accessible applications), developers are faced with a daunting task. To this end, numerous sets of guidelines to help developers produce systems that are accessible and usable by elderly and disabled people have been recently proposed and put in practice. These range from very general guidelines to the very specific guidelines for Web user agents, authoring tools, and content developers.

Nevertheless, it is questionable whether providing guidelines is an effective method for ensuring usable and accessible designs, since their usage alone requires specialised skills and since the provided guidance might be differently interpreted among developers and designers. Moreover, designers and developers are often required to select among a number of similar guidelines sets without clear understanding of which set is more suitable for their specific task at hand. Ultimately, the highly specialised skills required for developing accessible software sets aside most developers.

To mitigate such problems, developers should be guided in their development, as well as in their assessment process about accessibility concerns within ICT development. Thus, developers need a conceptual framework in which to situate disability-related guidelines, which they often do not have due to lack of experience with disabled population and their technologies.

Getting started from this need, comes the idea of ACCESSIBLE project, which develops for the first time a reliable and harmonized methodology and accompanying tools for large-scale accessibility assessment of products and services that cover the

domains of web applications, mobile-web applications, web services and Description Languages. Based on this Harmonised Methodology the accessibility assessment tools will be developed covering the following fields:

- Web applications.
- Web services.
- Mobile applications.
- Description Languages.

To this end, ACCESSIBLE will exploit the technologies behind the recent expansion of accessibility tools and standardisation methodologies, in order to provide an integrated simulation assessment environment for supporting the production of accessible software applications.

## II. ACCESSIBLE TOOLS PRESENTATION

The ACCESSIBLE develops and assessment module able to support the overall analysis and verification in terms of accessibility for Web and mobile applications, Web services and description languages (SDL, etc.). The module, which takes input from the ACCESSIBLE knowledge resources - ACCESSIBLE ontologies and Harmonized Methodology- is composed of independent accessibility assessment tools in order to support the overall accessibility assessment process. These assessment tools are summarized in the subchapters that follow.

### A. *Web applications accessibility assessment tool*

The Web Applications Accessibility Assessment Tool (WAAT) is an integrated tool that provides the users with the ability to validate a web application from the accessibility perspective. In the contrary with the majority of the today's market tools, the WAAT doing the evaluation according to the WCAG 2.0 guidelines, developed by WAI.

Through the WAAT, designers and developers can be assisted on accessible software application development, through relevant guidelines on accessibility constraints, errors and warnings that should be taken into account.

The adopted evaluation framework allows users (developers, designers, testers, etc.) to perform a personalized accessibility assessment process, though the selection of different accessibility

constraints (e.g. different types of impairments and disabilities, different sets of guidelines, personas). Thus the evaluation engine of the tool obtains the automatic tests corresponding to the set of accessibility requirements and constraints selected by the user. The main view of the tool is depicted in the figure 1. The list of errors and warnings, as well as the corresponding accessibility score for an evaluated Web page are depicted in figure 2.

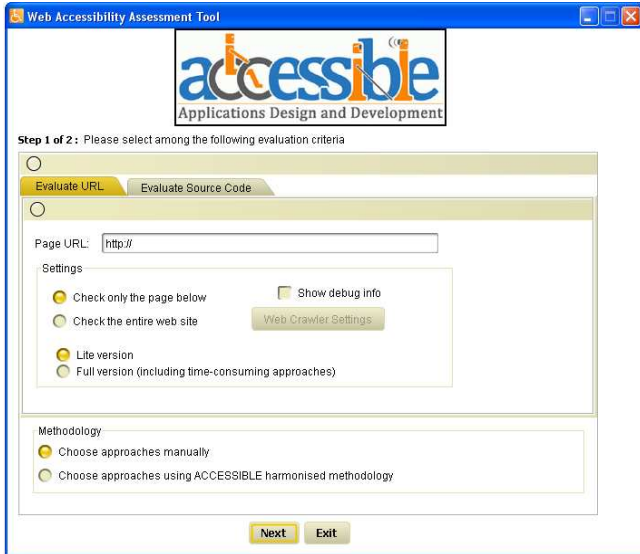


Figure 1. WAAT main window overview.

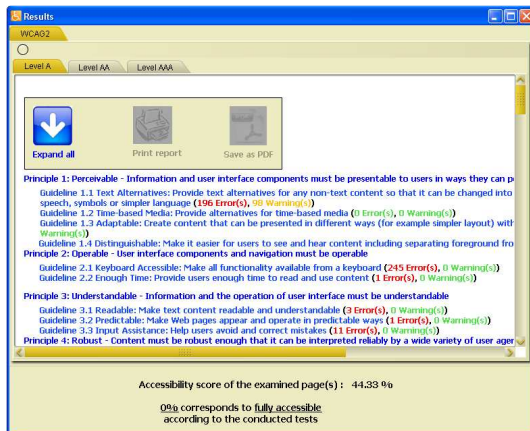


Figure 2. WAAT accessibility score for an evaluated Web page overview.

### B. Web services accessibility assessment tool

The Web services application assessment tool is based on the incorporated Harmonised Methodology (HAM) that has been developed in the content of ACCESSIBLE project [1]. Thus, the user has the opportunity to evaluate the accessibility assessment of preferable Web services against accessibility

constraints, guidelines and rules that have been incorporated in that specific methodology.

The tool provides to the designers a personalized accessibility assessment framework that can be used for the accessibility evaluation of Web services through the selection of different types of impairments and relevant accessibility factors. Through the tool the users can receive relevant feedback as well as the accessibility score concerning the detected accessibility errors and/or warnings that must be taken into account.

This tool is useful for all designers and developers who wish to create accessible Web services. Accessibility guidelines concerning Web services are introduced and they are mapped with impairments. Therefore, the tool can perform evaluation that is oriented towards the impairments that a potential user may have.

In figure 3 the main view of the Web Services Assessment tool is depicted. This figure also depicts the Guidelines that are used in order to evaluate a Web Service.

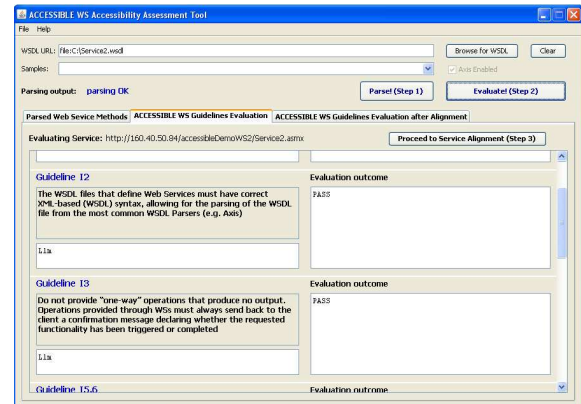


Figure 3. Web services accessibility assessment tool main window overview.

### C. Mobile-web applications accessibility assessment tool

The Mobile Web Adequacy and Accessibility assessment tool is based on the incorporated HAM methodology. The user has the opportunity to evaluate the mobile adequacy and accessibility assessment of Web pages against mobile web and accessibility constraints, guidelines and rules that have been incorporated in the HAM methodology, through the mobile access simulation available in the tool.

The adopted evaluation framework allows users (developers, designers, testers, etc.) to perform a personalized mobile adequacy and accessibility assessments, though the selection of different accessibility constraints (e.g. different types of impairments and disabilities, different sets of guidelines, personas). Through the tool the users can receive relevant feedback on errors and/or warnings that must be taken into account. This tool is useful for all designers and developers who wish to create mobile adequate and accessible Web sites. The main view of the tool and the list of errors and warnings for an evaluated Web page are depicted in Figure 4.

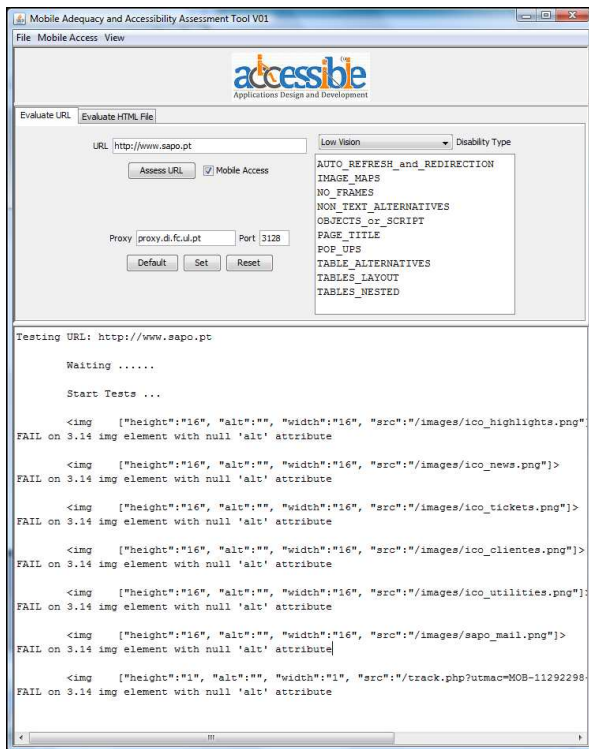


Figure 4. Web services accessibility assessment tool main window overview.

#### D. Description languages accessibility assessment tool

The description languages assessment tool allows the accessibility assessment of SDL (Specification and Description Language) application designs. Accessibility assessment is performed on the basis of the respective HAM evaluation approaches.

The selection of the evaluation approaches is performed either manually or through the selection of disabilities that are mapped onto guidelines and evaluation techniques. The output of the assessment tool comprises the evaluation result as well as

suggestions for correcting the detected shortcomings.

An overview of the description languages assessment tool is depicted in Figures 5, 6 and 7.

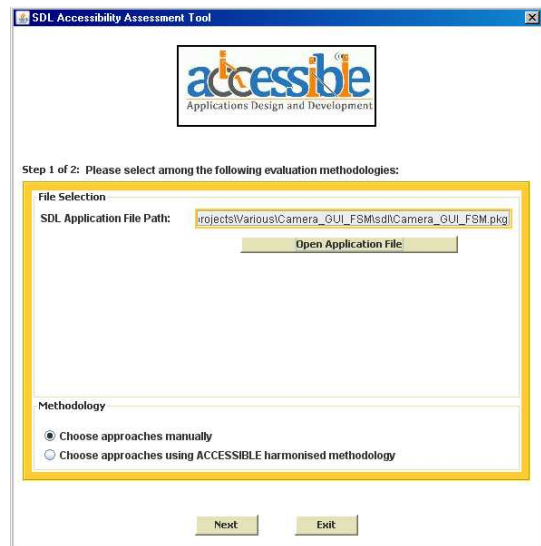


Figure 5. Web services accessibility assessment tool main window overview.

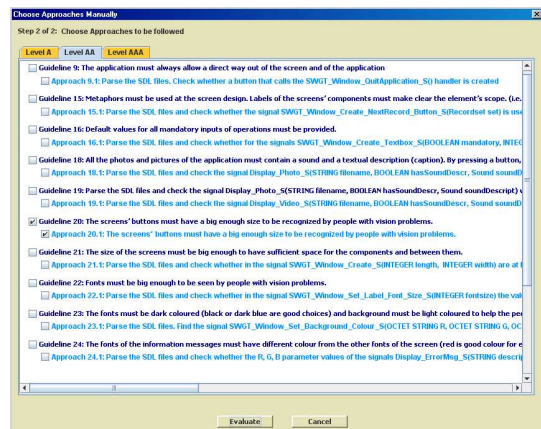


Figure 6. Web services accessibility assessment tool main window overview.



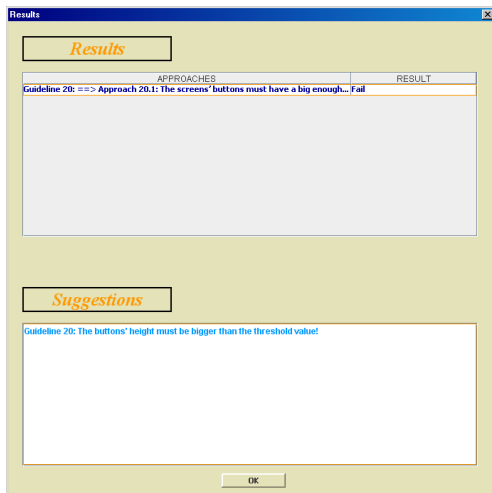


Figure 7. Web services accessibility assessment tool main window overview.

### III. USE CASES DESCRIPTION

When developing a system, within a research project that its scope and main purpose is to provide a solution to some problem in the user's environment (the "application domain"), the Use Cases have a critical role during the development process. The Use Cases are defined in order to provide the developer with another assistive tool, which will have the potential to guide him/her, in order to achieve the purpose of the project, in a more comprehensive and direct way.

A Use Case, as a description of an actor's interaction with the system to be developed, is both a description of the system's user interface and an indirect description of some functions that the system will provide, without showing how these functions are being achieved from the system (back-end info). In short, as descriptions of the new system, the Use Cases present the proposed solution to the problem in a simple and easy to understand way [8].

Thus, although the Use Cases constitute essential work towards the innovative ACCESSIBLE system development, other factors contribute also to the system success. Additionally, the first step in the requirements-gathering process must be the study and description of the problem-environment, the application domain. Thus, the initial step in the development of a system is to understand and study the problem instead of searching for the optional solution from the very beginning. So, before the researcher can effectively start building the solution to a problem, "first must concentrate on the

application domain, to learn what the problem is about." [9]. The aforementioned steps form a structured methodological framework and conclude to the extraction of the projects Use Cases.

#### A. Methodology

In order to extract the Use Case for a system to be, a methodological framework needs to be followed; despite the fact that the Use Case itself is not a methodology at all [10]. In the contrary, the UC is a description to preview and analyse the functionality of a specific system, aiming at capturing the interaction between the user and the system being developed. Thus, the main purpose of the Use Cases is to present in a detailed and also clear and easy-to-learn way, the functional requirements of a system. The Use Cases have the unique ability to help developers to understand the value that the system provides to its stakeholders [11]. In a simpler approach, the Use Cases describe who is doing what and when, and also what is expected from the system for each request. To this end, the Use Cases comprise a powerful tool to capture functional requirements for software systems to evaluate them [12].

In order to extract the ACCESSIBLE Use Cases, we followed a structured methodology starting from the User needs and System Requirements Specification, as well as from the State of the Art Survey in Accessibility Research. The ACCESSIBLE Use Cases and scenarios of use have been defined based upon literature review, on-site interviews, technological benchmarking and iterative consensus building among key stakeholders. Another component that was added in the ACCESSIBLE Use Cases extraction methodology was the link of the ACCESSIBLE personas to the respective Use Cases. The ACCESSIBLE personas have been derived from the findings of the ACCESSIBLE survey and extracted requirements, and have also been based and inspired by the ÆGIS Personas. The personas have been drawn up and adapted so as to fit to the projects needs and the Use Cases expectations.

The final Use Cases, as they have emerged from the prioritisation of the user needs survey, are presented in this Chapter. In each Use Case the following fields have been defined, following and adapting the fully dressed template for the Use Cases description:

- Use Case Title. A short title that indicates the scope of the specific UC.
- Brief Description. This includes the description of the main use case, which is the target of the user.
- Application area. To which application area of ACCESSIBLE the UC refers.
- Relevant WP. In which ACCESSIBLE WP the UC is being developed.
- Scenario. The title of the various scenarios for which the UC is consisted.
- Primary actor. This is the actor who initiates the use case and triggers the system.
- Secondary actor. This is the actor that does not participate directly in the UC but is being affected indirectly.
- Priority level. The ‘essential’ and ‘secondary’ UCs are the ones that have to be tested in the pilots tests, while the ‘supportive’ ones will be tested only if the specific UC is not covered/tested through another UC.
- System Input (trigger). This is the first action/request that is provided by one actor.
- System Output. It is the feedback and the reaction of the system to the Input (trigger).
- Resources required to perform the UC. Some UC may need specific resources like specific licence, software, NETBEANS, involved user equipment, etc. in order to be implemented properly and to be functional.
- Interaction step(s). Possible sequences of interactions to achieve the UC goal as series sequential steps of the system and the user.
- Connected UCs. This refers to any extension or connectivity of the current UC to other UCs.
- Relevant ACCESSIBLE personas.
- Background info. Information that explain the reason why this UC has been included.
- Reference
- Comments

The Use Cases that have been extracted and described, following the aforementioned template, have been separated in 5 different categories, namely:

- **Category 0: Generic Use Cases**
- **Category 1: Web applications**
- **Category 2: Mobile applications**
- **Category 3: Web services**
- **Category 4: Description languages**
- **Category 5: Visualisation (designer aid module)**

The detailed list of the ACCESSIBLE Use Cases accompanied with a short description of each one, is given below.

- **Category 0: System administration**
  - **UC 0.1 Administration**

The user wants to register, login, logout and the un-register of the ACCESSIBLE application/tool. This goal succeeds when the user obtains a confirmation, accepting his/her registration and becoming an ACCESSIBLE user, then the registered user gets in ACCESSIBLE services ambient and can achieve the available services, afterwards the user wants to log out of ACCESSIBLE system and finally the user obtains a confirmation on his/her un-registration.

- **UC 0.2 Standalone tool**

The user wants to install and then un-install the Stand Alone tool to his/her personal computer. This goal succeeds when the user has the means for achieving this goal in terms of facilities and at the same time the required feedback from the system for the successful or not completion of the installation/un-installation.

- **UC 0.3 Website Administration**

The user intends to administer the Website’s Content, users, Forum and documents, and also to access statistics regarding the created Assessment Projects. This goal succeeds if the user has the means for achieving these goals in terms of administrative facilities and at the same time the required feedback from the system, for the successful or not completion of administrative tasks.

- **UC 0.4 Ontology management**

The user requests to manage the ACCESSIBLE ontology. This goal succeeds if the user has effectively performed the management of the ACCESSIBLE ontologies.

- **UC 0.5 Rules User Interface**

The user wants to define a new accessibility assessment rule consisting of specific user requirements and checkpoints and save it in a self-defined guideline of a self-defined standard.

- **Category 1: Web applications**

- **UC 1.1: In-depth web application accessibility assessment.**

The user wants to realise an in-depth accessibility assessment of a Web application. This goal succeeds if the user has effectively performed the accessibility assessment of its preferable Web application through the selection of different categories of disabilities and impairments, relevant personas and other accessibility constraints. In the end the user should receive a detailed list of detected errors and warnings, the accessibility score, indicating the accessibility level of the evaluated web pages according to ACCESSIBLE tool, relevant guidance and assistance on correcting the detected errors and warnings and an EARL based report including relevant information about the evaluation results.

- **UC 1.2: Fast web application accessibility assessment**

The user wants to realise a fast accessibility assessment of a Web applications. This goal succeeds when the user has effectively performed the accessibility assessment of its preferable Web application through the selection of different categories of disabilities and impairments, relevant personas and other accessibility constraints. In the end the user should receive a detailed list of detected errors and warnings and the accessibility score, indicating the accessibility level of the evaluated web pages according to ACCESSIBLE tool.

- **Category 2: Mobile applications**

- **UC 2.1: In-depth mobile-Web accessibility assessment for developers**

The user wants to realise an in depth accessibility assessment of mobile-Web content. This includes the Mobile Web Content assessment tool through the incorporation of the HAM methodology. Thus, the user performs the accessibility assessment of web content against mobile adequacy and accessibility guidelines and rules that are incorporated in the HAM methodology. The tool provides to evaluators a personalized accessibility assessment framework of errors and warnings with the accessibility score, as well as relevant guidance and assistance on correcting the detected errors and warnings and an EARL based report including relevant information about the evaluation results.

- **UC 2.2: Fast mobile-Web accessibility assessment for developers**

The user wants to realise a short accessibility assessment of Mobile Web content. This includes the Mobile Web Content assessment tool through the incorporation of the HAM methodology. Thus, the user performs the accessibility assessment of web content against mobile adequacy and accessibility guidelines and rules that are incorporated in the HAM methodology. The tool provides to evaluators a personalized accessibility assessment framework with a detailed list of detected errors and warnings and the accessibility score.

- **UC 2.3: In-depth mobile Java FX accessibility checker**

The user wants to realise an in-depth accessibility assessment of Java FX script applications. Using the Java FX accessibility system, the user performs the accessibility assessment of a preferable Java FX application against accessibility constraints. This goal succeeds if the user has effectively performed the accessibility assessment of its preferable JavaFX script applications and receives a list of accessibility errors and warnings, as well as, guidance to fix them accompanied with an EARL based report including relevant information about the evaluation results.

- **UC 2.4: Fast mobile Java FX accessibility checker**

The user wants to realise a fast accessibility assessment of Java FX script applications. Using the Java FX accessibility system, the user performs the accessibility assessment of a preferable Java FX



application against accessibility constraints. This goal succeeds if the user has effectively performed the accessibility assessment of its preferable JavaFX script applications and receives a list of accessibility errors and warnings.

- **Category 3: Web services**
  - **UC 3.1: In-depth web services accessibility checker for the developers**

The user wants to realise an in-depth accessibility assessment of Web services. This goal succeeds if the user has effectively performed the accessibility assessment of its preferable web service and receives a list of assessment results (pass, fail) concerning each web service guideline, the accessibility score (level A, AA, AAA) that indicates the accessibility of the evaluated web service and an EARL based report including relevant information about the evaluation results.

- **UC 3.2: Fast web services accessibility checker for the purchaser**

The user wants to realise a fast accessibility assessment of Web services. This goal succeeds if the user has effectively performed the accessibility assessment of its preferable web service and receives a list of assessment results (pass, fail) concerning each web service guideline. The accessibility score (level A, AA, AAA) that indicates the accessibility of the evaluated web service.

- **Category 4: Description languages**
  - **UC 4.1: Description languages accessibility checker for the developer**

The user wants to realise an in-depth accessibility assessment of SDL designs of applications. It is based on the use of the description languages accessibility assessment tool. The user (application designer) performs the accessibility assessment of the SDL design of an application against predefined accessibility guidelines and rules. The tool provides to evaluators an accessibility assessment framework that can be used for the accessibility evaluation of SDL designs of applications through the selection of different categories of impairments and other accessibility constraints. Through the use of the tool designers can be assisted on the design and

development of accessible software applications based on the potential detected accessibility limitations.

- **Category 5: Visualisation (designer aid module)**
  - **UC 5.1: Disability Impairment Approximation Simulator**

The user wants to have an embedded accessibility design for the development of Java Swing graphical user interface applications. Presenting an advanced disability approximation simulator, “authors” can obtain a better understanding of the accessibility constraints for impaired users within a Java Swing application by simulating each element.

#### IV. EVALUATION METHODOLOGY

The Use Cases present the core of the ACCESSIBLE projects since they illustrate the functions that the outcomes of the ACCESSIBLE project should fulfil, as well as the interrelation of the system with the user. The evaluation of the ACCESSILBE prototype will be done based upon the aforementioned Use Cases. This evaluation is a step that has not yet been realised within ACCESSILBE, even though it has been planned in a User Centred iterative methodology. This methodology has been defined in the pilot plans of the project and it is illustrated in the figure 8.

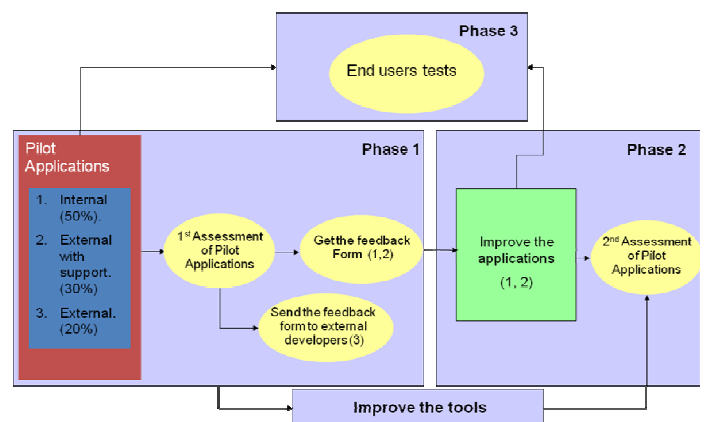


Figure 2. ACCESSIBLE prototype evaluation methodology.

The evaluation of the ACCESSIBLE tools will involve the assessment and improvement of the accessibility level of a set of selected pilot

applications. The pilot applications are categorised as follows:

1. **Internal applications** that have been developed by the project partners.
2. **External applications** that have been developed by organisations outside the consortium who will be invited to assess and improve the applications accessibility level **with the support of the ACCESSIBLE partners** (tool developers).
3. **External applications** that have been developed by organisations outside the consortium and for which accessibility assessment will be performed by the ACCESSIBLE partners. The accessibility assessment results will then be communicated to these organisations.

The ACCESSIBLE prototype and implemented modules will be evaluated in a series of pilots that will be planned and realized within the running period of the project.

Three main types of technology evaluation activities are foreseen:

1. **Evaluation from the developer's perspective**, i.e. in terms of functionality, performance, reliability and usability as perceived by the users of the tools. Evaluation activities of this type will be exercised during Pilot Phases 1 and 2.

The evaluation subjects will be software professionals that are active in the development of applications in the sectors relating to the four ACCESSIBLE pilot application areas. More specifically, the desired technological competencies should be identified within one or more of the following five main fields:

- a. *Web applications development*
- b. *Mobile Web applications development*
- c. *Service Oriented Architecture (SOA) technology and Web Services development*
- d. *Design of applications using the Specification and Description Language (SDL)*
- e. *Java Swing Graphical User Interface (GUI) applications development*

For all the above cases, priority will be given to professionals who are acquainted with accessibility-related software development practices and

standards (e.g. WCAG 1.0, WCAG 2.0, MWBP 1.0).

At least five (5) software experts will participate in each of the concerned trials.

2. **Evaluation from the technical perspective**, i.e. in terms of performance, software modularity, maintainability, extendibility, and functionality as measured and perceived by technical evaluation teams that will perform extensive tests and measurements as well as examine the source code of the different ACCESSIBLE tools. Evaluation activities of this type will be exercised during Pilot Phase 2.

The following main groups of evaluation subjects have been identified:

f. **Software professionals** (who will not have been involved in the development of the ACCESSIBLE tools) including designers, software analysts, developers, and testers. The desired technological competencies include software analysis and design, software development (Java, C++, C#), software testing practices, knowledge management technologies, etc.

g. **Service administrators** with professional experience in IT services maintenance and administration.

At least ten (10) experts will participate in this trial.

3. **Evaluation from the end-user's perspective**. Elderly and disabled end-users will be invited to assess the improvement of the accessibility level of the applications that were tested using the ACCESSIBLE tools. **Evaluation activities of this type will be exercised during Pilot Phase 3.**

## V. CONCLUSIONS

The need of accessibility and accessible design is profound in all fields of everyday living and activities, especially in the ICT environment. Efforts towards the awareness for accessibility have been thriving the last decade especially from the European Union, as well as from USA. Various accessibility guidelines have been developed in order to fulfil the accessibility target especially in the web domain. This resulted to the non-

standardized and non orthological development of the accessibility assessment domain, fact that makes the efforts for accessibility design form the developers even harder.

To this end the ACCESSIBLE project has developed a reliable and harmonized methodology and accompanying tools for large-scale accessibility assessment of products and services that cover the domains of web applications, mobile-web applications, web services and Description Languages. In the current paper the aforementioned tools have been illustrated and described in short.

For the evaluation of the usability, the utility and the user satisfaction for the ACCESSIBLE prototype, the evaluation of the tools is needed. The evaluation phase is based upon the project's Use Cases that have been presented in the current paper. Following a structured and already successfully implemented methodology, we were guided from the user need and the system requirements specifications, to the extraction of the personas and the correlation of them with all the accessibility components through the Harmonised Methodology, to finally extract the ACCESSIBLE Use Cases. The ACCESSIBLE Use Cases cover all the field of the project and fulfil all the user needs and requirements.

Finally, the ACCESSIBLE prototype is going to be evaluated using the aforementioned Use Cases, following the iterative, 3step, user oriented evaluation strategy.

#### ACKNOWLEDGMENT

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# Enforcing Accessible Design of Products and Services Through Simulated Accessibility Evaluation

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**Abstract**—The present paper introduces a framework that enables the simulated accessibility evaluation of ICT and non-ICT products and services at all the stages of the development. The proposed framework is based on an innovative virtual user modelling technique describing in detail all the physical parameters of the user with disability. The proposed user modelling methodology generates a dynamic and parameterizable virtual user model that is used in a simulation framework to assess the accessibility of the designs. Experimental results illustrate the use of the proposed framework in a realistic application scenario.

**Keywords**-accessibility evaluation; user modelling; task modelling; simulation; UsiXML; virtual user

## I. INTRODUCTION

As global populations are growing older, together with an increase in people with disabilities [35], the moral and financial need for “designed for all” [3] products and services becomes obvious. Design for All means developing mainstream products and services so that as many people as possible can use them easily. This does not mean that manufacturers are expected to design every product to be usable by every consumer - there will always be a minority of disabled people with severe impairments who need adaptations or specialised products. But when Design for All principles are adopted, fewer people will require specialised and expensive alternative equipment.

The excuse that it is people's specific characteristics that prevent them from using mainstream goods and services is not acceptable.

We all get older and our needs change with age. Hearing, vision, mobility and strength impairments are common to the aging process. Goods and services can and should be designed to meet the needs of a wide range of people, including those with disabilities. Product designs can be changed, but people's abilities or age cannot.

The lack of non accessible products can cause large productivity losses, with many people being unable to fully participate at work, in education, or in a wide range of economic and social activities. People's choice of leisure activities may be narrower than it otherwise could be. Thus, it is a technological challenge to provide senior citizens with systems that could foster the different facets in the perception of quality of life. These systems should improve the level of independence, promote the social relationships, leverage the immersion in the environments and encourage the psychological and physical state of the person.

The design solutions needed include both redesign of existing products and innovation of new products to satisfy user needs in an efficient and effective way. Improvement in existing daily-life equipment or invention of new utilities is more than a matter of intention and good will. It should be based upon and inspired by knowledge of the characteristics of the intended users, i.e. their habits, needs, capabilities and limitations relevant to the handling of products and services.

Virtual User Modelling can play an important role in human-centric design of products and services. Generally, a Virtual User Model aims to replicate the human body in form and function as realistically and accurately as possible. Virtual User Models can be used to refine designs before prototypes are needed, shortening design time to the market and reducing costs.

Even if there have been some limited and isolated attempts [24][30] to support accessibility testing of novel products and applications, there is a clear lack of a holistic framework that supports comprehensively virtual user modeling, simulation and testing at all development stages. The present paper presents a framework that performs automatic simulated accessibility evaluation based on a new user modeling technique. The great importance of such a framework lies to the fact that it enables the automatic accessibility evaluation of any environment for any user by testing its equivalent virtual environment for the corresponding virtual user. Moreover, the main innovation of the proposed framework lies in the fact that, the whole framework is based on a new virtual user modelling technique including physical, cognitive and behavioral/psychological aspects and parameters of the user with disability. The proposed technique is not constrained in static modelling of the virtual user but generates a dynamic and parameterizable user model including interactions that can be used directly in simulation frameworks, adaptive interfaces and optimal design evaluation frameworks.

## II. RELATED WORK

Different user model representations have been proposed in the literature using different syntaxes and implementations, varying from flat file structures and relational databases to full-fledged RDF with bindings in XML.

OntobUM [27], the first ontology-based user modelling architecture, was introduced by Razmerita et al. in 2003. OntobUM integrated three ontologies: a user ontology characterizing the users, a domain ontology defining the relationships between the personalization applications, and a log ontology defining the semantics of user-application interaction. A similar, but way more extensive approach for ontology-based representation of the user models was presented in [12]. GUMO, probably the most comprehensive publicly available user modelling ontology to date, is proposed in [11]. The need for a commonly accepted ontology for user models is also justified. These works are natural extensions of earlier works on general user modelling systems [13], [14], [16].

XML-based languages for user modelling have also been proposed. UserML has been introduced in

[10] as user model exchange language. UserML is based on an ontology that defines the semantics of the XML vocabulary (UserOL).

The use of “personas”, which are empirically based abstract descriptions of people has gained popularity and has been developed into a well documented design practice [4], [8], [22], [23], [26]. Pruitt et al. [26] claim that currently there are no explanations of why many prefer to develop personas, instead of focusing directly on the scenarios that describe the actual work processes that the design is intended to support. However, a potential candidate to a theory of using ‘personas’ in design is, according to Pruitt et al. [26] the ‘theory of mind’ that says that we, as humans, always use our knowledge of other people’s mental states to predict their behaviour [2]. So, after HCI researchers have struggled for years to expand the original cognitive basis for HCI to include a concept of the individual’s environment [9], [33], a renewed focus on mental representations seems to arise from research as well as from experience from design practice.

In the context of cognitive modelling, [SOAR](#) [28] offers a general cognitive architecture for developing systems that exhibit intelligent behavior. It defines a single framework for all tasks, a mechanism for generating goals and a learning mechanism. Moreover, a single representation of permanent and temporary knowledge is provided. All decision computations are made through the combination of relevant knowledge at run-time. Another popular cognitive architecture is [ACT-R](#) [1], which is based on the distinction between declarative and procedural knowledge, and the view that learning consists of two main phases. In the first phase the declarative knowledge is encoded and in the second it is turned into more efficient procedural knowledge [21].

Virtual User Models are already used in application areas such as automotive and aviation design. The RAMSIS human modelling tool [20] is currently used in the design of automobiles in about seventy percent of auto-manufacturers. SAMMIE is a computer aided human modelling system that represents a widely used tool to accommodate the needs of a broad range of differently sized and shaped people into the design of products [29]. SAMMIE has been successfully developed and



employed in a large number of industrial, commercial and government projects. However, the successful use of tools such as SAMMIE is often constrained by the need for ‘expert’ users. HADRIAN [19] is another computer-based inclusive design tool that has been developed to support designers in their efforts to develop products that meet the needs of a broader range of users.

### III. MODELLING FRAMEWORK

In order to support the automatic accessibility testing of ICT and non-ICT services and products, it is essential to create machine-readable descriptions of the disabled user and the tasks that the user is able to perform, as well as formal descriptions of the products and services to be tested. The present paper introduces the concepts of Virtual User Model, Task Model and Simulation model, respectively, all expressed in UsiXML format. The universal description of User, Task and Simulation Models with the extensible UsiXML language is a major step towards the interoperability and practical implementation of embedded accessible product solutions. In the context of the proposed framework, the aforementioned models are used by the core component of the proposed framework, the Simulation Module.

More specifically, the Simulation Module gets as input a Virtual User Model (describing a virtual user with disabilities), a Simulation Model that describes the functionality of the product/service to be tested, the Task Models that describe in detail the complex tasks of the user and simulates the interaction of the virtual user (as it is defined in the Simulation Model) within a virtual environment.

#### A. Virtual User Model

A Virtual User Model (Figure 1) describes an instance of a virtual user, including user’s preferences, needs and capabilities and is modelled through an extension of UsiXML.

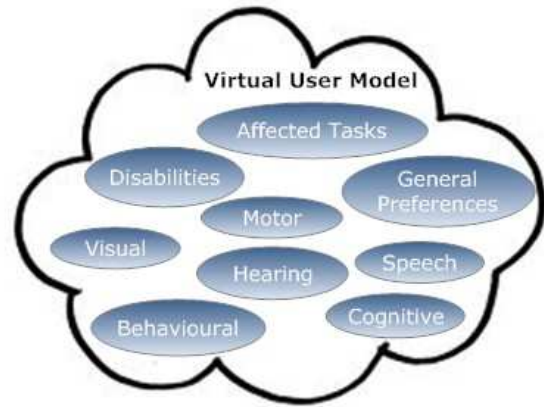


Figure 1. A Virtual User Model describes all the possible disabilities of the user, the affected by the disabilities tasks, the motor, visual, hearing, speech, cognitive and behavioural user characteristics as well as some general preferences of the user.

A Virtual User Model includes:

- General user preferences
  - e.g. preferred input/output modality, unsuitable input/output modality, etc.
- Disabilities
  - e.g. arthritis, glaucoma, etc.
- Affected tasks
  - e.g. grasping, driving, etc.
- Motor parameters
  - e.g. wrist flexion, forearm pronation, hip abduction, etc.
- Visual parameters
  - e.g. visual acuity, contrast sensitivity, etc.
- Hearing parameters
  - e.g. resonance frequency, etc.
- Speech parameters
  - e.g. voice pitch, syllable duration, etc.
- Cognitive parameters
  - e.g. memory, etc.
- Behavioural parameters
  - e.g. valence, emotional intelligence, etc.

Despite the fact that the proposed structure of the Virtual User Models is designed to include motor,

visual, hearing, speech, cognitive, and behavioural disabilities, currently only motor disabilities are supported by the proposed Simulation Platform, described in section IV.

### B. Task Model

The task models describe the interaction between the virtual user and the virtual environment. The population of the task models is based on the analysis of:

- User Actions/Interactions: motor, cognitive and sensory abilities, such as the user’s ability to handle a specific task (e.g. to overcome physical obstacles such as narrow passageways in the construction area), to perceive visually presented information to select objects on a specific user interface, etc.
- Domain knowledge and relevant attributes with respect to the contents of application scenarios such as automotive, smart living spaces and building, domotics, infotainment, health, etc.

User tasks are divided into primitive (e.g. grasp, pull, walk, etc.) and complex (e.g. driving, telephone use, computer use, etc.). For each complex task a Task Model is developed, in order to specify how the complex task can be analyzed into primitive tasks (as they have been defined by the designers/developers according to the functionality of the prototypes to be tested in terms of accessibility). For the development of the task models of the proposed framework the *taskModel* element of UsiXML is being used.

TABLE I. A COMPLEX TASK AND ITS PRIMITIVES

Complex task	Primitive tasks
Open top drawer with left hand	Find top drawer (visual)
	Move left hand to top drawer (motor)
	Grasp top drawer with left hand (motor)
	Pull top drawer with left hand (motor)

Table I presents an example of a complex task and the primitive tasks in which it could be analyzed

into. Figure 2 presents a schematic description of this task model and Table II depicts how it could be expressed in UsiXML format.

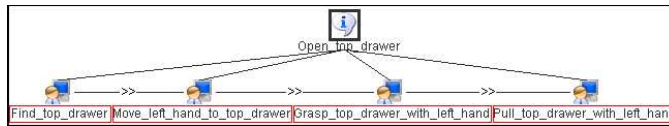


Figure 2. Task Model example – The root node represents a complex task while the leaf nodes represent primitive tasks. The arrows between the primitive tasks mean that the primitive tasks should be executed sequentially.

TABLE II. TASK MODEL EXAMPLE – USIXML FORMAT

```

<?xml version="1.0" encoding="UTF-8"?>
<taskmodel>
<task id="st0task0" name="Open_top_drawer"
type="abstraction">
<task id="st0task1" name="Find_top_drawer"
type="interaction"/>
<task id="st0task2"
name="Move_left_hand_to_top_drawer"
type="interaction"/>
<task id="st0task3"
name="Grasp_top_drawer_with_left_hand"
type="interaction"/>
<task id="st0task4"
name="Pull_top_drawer_with_left_hand"
type="interaction"/>
</task>
<enabling>
<source sourceId="st0task1"/>
<target targetId="st0task2"/>
</enabling>
<enabling>
<source sourceId="st0task2"/>
<target targetId="st0task3"/>
</enabling>
<enabling>
<source sourceId="st0task3"/>
<target targetId="st0task4"/>
</enabling>
</taskmodel>

```



### C. Simulation Model

A Simulation Model refers to a specific product or service and describes all the functionalities of the product/service as well as the involved interaction with the user, including all the different interaction modalities supported. The Simulation Models are also expressed using the *taskModel* element of UsiXML.

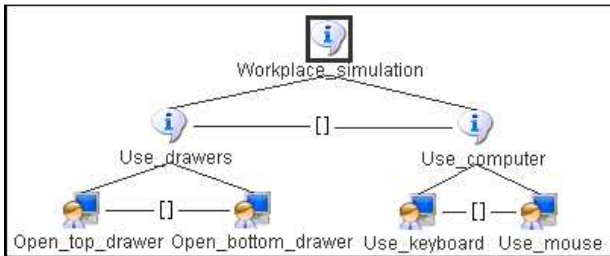


Figure 3. A Simulation Model example representing all the possible tasks that can be performed in a common workplace interior, which includes a stack of drawers and a computer. The tasks of the same level are connected with choice relationship, which means that one of the two can be executed at a time.

Figure 3 presents a simulation model referred to a workplace interior including a stack of drawers and a computer. According to this simulation model, the interaction between the user and the environment includes the opening of the drawers as well as the keyboard and mouse use.

### D. User Model Editor

In order to enable the automatic generation of Virtual User Models in UsiXML format and, thus, enforce the proposed virtual user modelling methodology, a software tool has been developed. The graphical user interface of the User Model Editor includes a set of forms (Figure 4, Figure 5) enabling the setting/editing of every parameter of the Virtual User Model. Moreover, a preview of the generated model is offered, as depicted in 0Load capability of previously saved Virtual User Models is also offered.

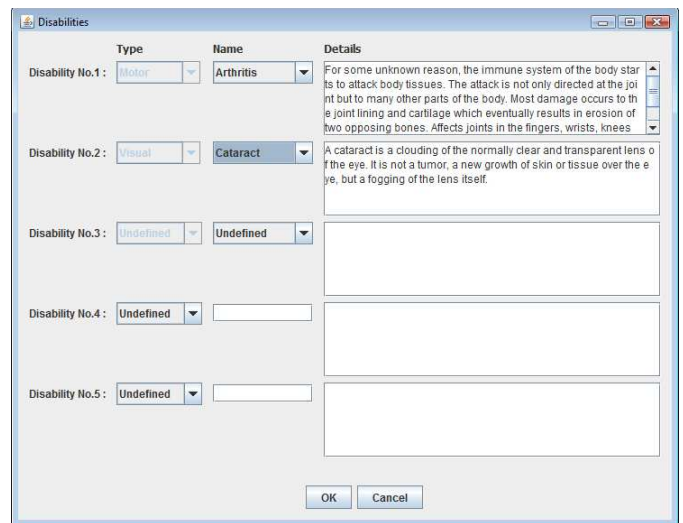


Figure 4. Virtual User Model Generator – Add/Edit disabilities form. The designer can easily define the type, the name and the details of all the possible disabilities.

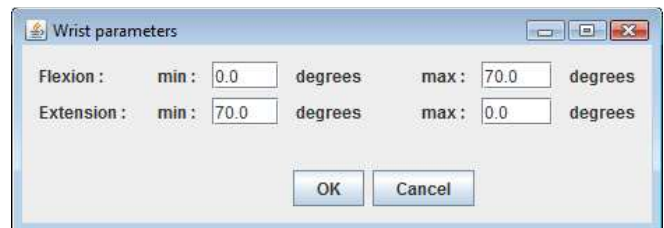


Figure 5. Virtual User Model Generator – Edit motor parameters example form. The designer is able to define the range of wrist's flexion/extension for each hand of the user.



Figure 6. Virtual User Model Generator – Model Preview. The preview window presented to the right offers the designer a generic view of the generated Virtual User Model.

## IV. SIMULATION PLATFORM

### A. Virtual Environment

The proposed framework performs automatic simulated accessibility evaluation in virtual environments, thus virtual environments have to be developed according to the specifications of the real ones to be tested. The virtual environment is used by the Simulation Module, which is the core module of the proposed framework and performs the evaluation process.



Figure 7. Virtual environment example representing a common workplace interior, which includes among others a stack of drawers and a computer. The drawers' opening task as well as the computer use could be simulated in the proposed Simulation Platform for different Virtual Users.

Figure 7 depicts a virtual environment representing a common workplace interior, which includes among other a stack of drawers and a computer.

It is obvious that the credibility and the accuracy of the simulation results lie on the detailed representation of the virtual environment, which will be given as input to the Simulation Module.

#### 1) Simulation Module

The Simulation Module gets as input a Virtual User Model (describing a virtual user with disabilities), a Simulation Model that describes the functionality of the product/service to be tested, the Task Models that describe in detail the complex tasks of the user and a virtual 3D environment representing the product/service to be tested. It then simulates the interaction of the virtual user (as it is defined in the Simulation Model) with the virtual environment. Then the specific disabled virtual user is the main "actor" of the physically-based

simulation that aims to assess if the virtual user is able to accomplish all necessary actions described in the Simulation Model, taking into account the constraints posed by the disabilities. Even if the proposed framework is designed to include cognitive, behavioral and physical disabilities, in the present work, first results on the modeling and simulation of motor arm disabilities are reported. Simulation planning is performed using inverse kinematics, while dynamic properties of the human limbs (e.g. forces) related to the corresponding actions (e.g. grasping) are obtained using inverse dynamics.

The simulation module is parted of three basic elements: a) the scene module, b) the humanoid module and c) the task manager module (Figure 8). The scene module is responsible for the representation of the scene and the management of all the objects in it. The humanoid module represents the human model and controls the humanoid's movements. The task manager module defines the interactions between the humanoid and the scene objects in a specific manner defined by the task models. The modules are further explained in the following paragraphs.

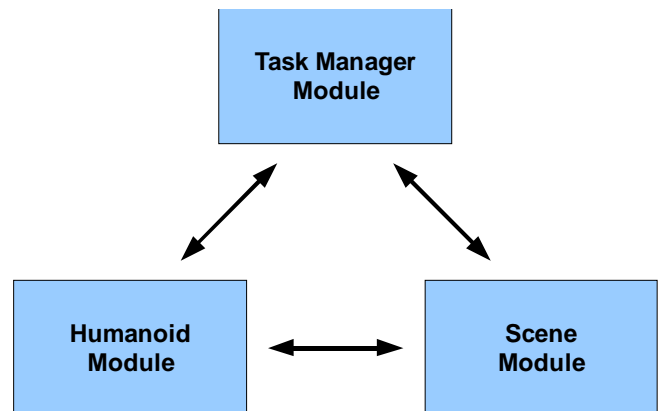


Figure 8. The basic elements of the simulation module

The simulation implementation is based on the Delta3D open source gaming and simulation engine [5]. Open Dynamics Engine [32], as part of Delta3d, is used for its collision detection methods and for implementing the dynamic part of the simulation (forces and torques).

## 2) Scene module

The scene module is responsible for creating the scene, adding the objects in it and defining their special attributes.

The scene is modeled by two sets of objects: static objects and moveable objects. Both objects have geometry (volume) and visual representation (textures). Static objects do not have mass and cannot be moved by the humanoid. On the other hand, moveable objects are modeled as rigid bodies, having properties like uniformly distributed mass over their volume (constant density), linear and angular velocity. Complex objects, can be modeled by using a combination of static and moveable objects, and manually defining the degrees of freedom of the moveable parts.

Special points of interest (POI) can be declared on the objects to best define the type of interaction with the humanoid. These points can be used to help the humanoid to interaction with the object, but they do not define the interaction. Their only purpose is to decrease the complexity of the task.

As an example of a complex scene object, it will be mentioned the case of a stack of drawers. Each drawer can be modeled as moveable object. The stack-base does not move, and thus can be modeled with a static object. Two POI can be also assigned to each drawer's handle-knob to help the humanoid interact with the object.

Collision between the objects and properable contact reaction is fully supported by the scene module. A moveable object can collide with either a moveable/static object or with the humanoid. Various attributes such as surface object material properties need to be defined for a realistic friction model. In order to decrease the dynamical complexity of the scene, gravitational forces can be applied only to the moveable objects.

## 3) Humanoid module

The human is modeled by a skeletal model that is represented by a set of bones and a set of joints. A total of 46 bones and 45 joints compose the humanoid's skeleton. The skeletal model is following a hierarchical approach, meaning that each joint connects a child bone with its parent one. Basically, the bones are modeled by rigid bodies, having properties like mass, volume, position, velocity etc. The mass is distributed uniformly in the

bone's volume. A primitive geometry shape (box, sphere or capsule) is attached to each bone, which is representing the human part flesh and is used for collision testing purposes (Figure 9).

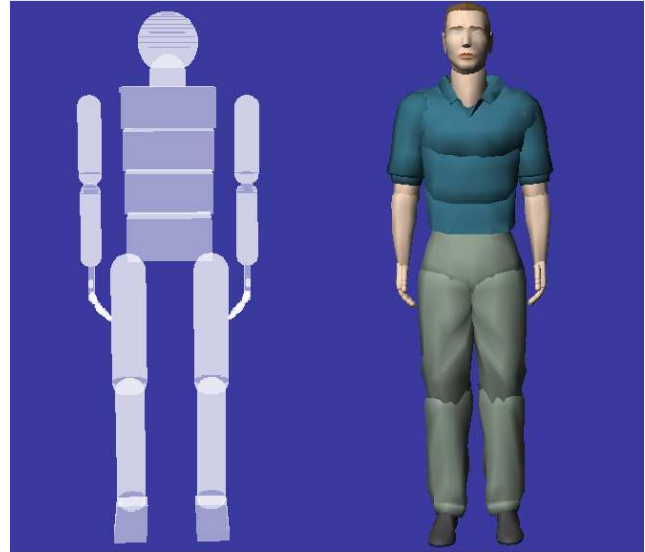


Figure 9. Humanoid avatar: the collision primitive bodies (left image) and the humanoid final representation (right image).

The joints restrict the movement of their attached bones and have properties like:

a) *rotational degrees of freedom*: these define the rotational axis in which the attached child bone is able to rotate relatively to its parent. Every joint can have one to three degrees of freedom.

b) *minimum and maximum angle per degree of freedom*: basically, these two angles constrain the range of motion of the attached bones (and their body parts).

c) *minimum and maximum joint torque*: these are an abstract representation of the muscles attached to the joint.

Currently, the model supports two basic modes: kinematic and dynamic. In kinematic mode, the humanoid moves by directly changing the position and orientation of each bone part per time step. Forward and inverse kinematic (IK) techniques are supported: the kinematic model can be moved either by manually changing a set of specific joint angles or by finding the change in these angles by using an inverse kinematic chain. The latter has as input the final position and/or orientation of its end effector, e.g. hand, and computes the angles of every joint in the IK chain, e.g. elbow and shoulder joint.

In dynamic mode, the humanoid changes its state, by applying torques at each joint. As above, forward and inverse dynamic techniques [6] are supported. In the forward dynamics case, the joint torques are manually set. Inverse dynamic techniques automatically compute the torques that need to be applied at the joints in order to achieve a specific motion.

Various high level motion planning and collision avoidance techniques are supported by the humanoid module. Configuration space [18] and structures that define and explore it, such as rapidly exploring random trees [17] and multi-query planners [31] are extensively used in order to compute a non colliding path for the humanoid.

#### 4) Task Manager Module

The task manager module is responsible for managing the actions of the humanoid in order to provide a solution to a given task. After splitting the complex task to a series of primitive tasks, the task manager instructs the humanoid model to perform a series of specific movements in order to accomplish them.

Primitive tasks, like reach, grasp, pull, push, are translated via the task manager module to series of specific motions and are inserted to the humanoid module for application. There are several ways of mapping primitive tasks to humanoid movements. For simple tasks such as reach, the usage of inverse kinematic chains produces satisfactory results. For more advanced primitive tasks such as grasp-object, pull-object, specific solvers must be implemented. Currently, solvers for grasping and push-pull tasks have been constructed. Their input are some predefined POIs (see scene module’s description – section IV, paragraph B.1) of the manipulated scene object.

At every step, the task manager, as supervisor, checks for task completion and reports to the system if something went wrong. The cycle pattern that is followed at each simulation step in the dynamic mode is shown in Figure 10.

More precicely, at the start of the cycle, the Task Manager module generates a series of movements (i.e. movement path) for the humanoid to follow. Every state of the generated path must contain information about the target configuration of the bones and joints  $C_{task}$ . Collision avoidance

techniques are applied at this step so that the humanoid geometry does not penetrate its own elements or any scene object. If a path cannot be found after a number of iterations in search space then the task manager reports task failure to the system.

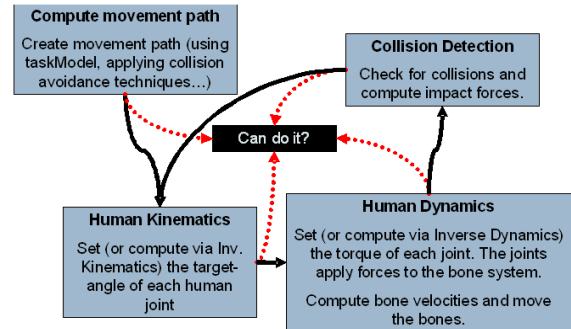


Figure 10. Block diagram of the simulation cycle followed by in dynamic mode. The simulation cycle is repeated until every primitive task is completed. At each step the task manager module tests and reports to the user if a constraint (i.e. angle/torque limit, collision, etc.) was violated.

After that, the task manager, provides the humanoid model with the current target configuration  $C_{task}$ . The humanoid gets the provided configuration and applies to it a set of restrictions, such as joint-angle restrictions. Angle-constrained inverse kinematics methods are used in order to find a new configuration  $C_{constrain}$  that is close to the targeted one ( $C_{task}$ ).  $C_{constrain}$  contains a target angle for each of one of the joints. If the difference between  $C_{task}$  and  $C_{constrain}$  is above a limit then the Task Manager reports failure. The difference metrics that have been tested are: a) average distance of the joints’ positions in  $C_{task}$  and  $C_{constrain}$ , b) average distance only end effectors’ positions, c) average angle absolute difference of each joint angle.

Having a target angle for each joint, the system computes via inverse dynamics the torques that need to be applied at each joint and set the attached bones in motion. If the computed torques’ values exceed the predefined limits, the task will fail. This step is valid only when simulation is running in dynamic mode. In kinematic mode, this step is omitted and the targeted angles are set directly.

## V. EXPERIMENTS

In order to show how the proposed framework could be used in practice, an evaluation scenario is presented in this section. According to the scenario,



a designer of a common workplace interior performs accessibility evaluation of a prototype for different virtual users with disabilities.

The designer initially develops the virtual workspace prototype presented in Figure 7. Then, using the Virtual User Model Editor, the designer generates five Virtual User Models, whose problematic physical parameters are presented in Table III. Two Task Models describing the opening of the top and bottom drawer, respectively, were developed in the context of the experimental scenario (in a similar way such as the Task Model presented in Figure 2). Finally, a simple Simulation Model describing the interaction of the Virtual User in the specific virtual environment will be used to assess the accessibility of the designs (Figure 11).

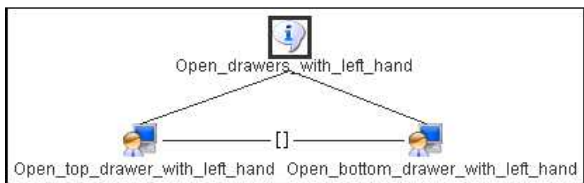


Figure 11. The tasks that the Simulation Platform will simulate for the Virtual Users are described by the two leaf nodes.

The opening of the top and bottom drawer (as described by the Simulation Model of Figure 11) was simulated for all the virtual users in two different scenarios. In the first scenario, the drawers were on the desk while in the second one the drawers were below the desk.

The results of the simulation process clearly revealed accessibility issues of the specific

workplace regarding only some of the disabilities described in the Virtual User Models. More specifically, as depicted in Table IV, the virtual users with rheumatoid arthritis and adhesive shoulder capsulitis, respectively, failed in all the tasks, which means that the specific environment is inaccessible for them.

The virtual user with spinal cord injury was able to perform all the tasks successfully, except from the opening of the bottom drawer when the drawers were below the desk. Finally, the simulation results showed that the virtual environment was fully accessible for the virtual user with hemiparesis and the elderly virtual user, as they completed all the tasks successfully.

## VI. DISCUSSION

The proposed framework is seen to be very promising as it enables the simulated accessibility evaluation of products and services for any possible disability but it should be mentioned that the credibility of the simulation results lies on the detail and the scientific accuracy of the models given as input to the Simulation Module as well as the detail of the corresponding virtual environment.

Currently the humanoid is represented by a skeletal system. Future extensions of the proposed framework will be examined, in order to support a muscle system applying forces and torques to the bones and, thus, offering more realistic simulation results.

TABLE III. VIRTUAL USER MODELS - DETAILS

Physical characteristics	Normal values	Rheumatoid arthritis [25]	Spinal cord injury [7]	Adhesive shoulder capsulitis [15]	Hemiparesis [35]	Elderly man 75-79 [34]
Wrist flexion (°)	0 - 60					0 - 62
Wrist extension (°)	0 - 60				0 - 67.48	0 - 53
Shoulder flexion (°)	0 - 180	0 - 10	0 - 118	0 - 20	0 - 53.39	
Shoulder abduction (°)	0 - 90	0 - 15	0 - 74	0 - 10		
Shoulder internal rotation (°)	0 - 90					
Shoulder external rotation (°)	0 - 50	0 - 15	0 - 31	0 - 10		
Forearm supination (°)	0 - 85					
Elbow flexion (°)	0 - 150				0 - 91.09	

TABLE IV. SIMULATION RESULTS

Task		Rheumatoid arthritis	Spinal cord injury	Adhesive shoulder capsulitis	Hemiparesis	Elderly
Drawers on desk	Open top drawer	 Simulation result: <b>Failure – Shoulder joint limit</b> (a1)	 Simulation result: <b>Success</b> (b1)	 Simulation result: <b>Failure – Shoulder joint limit</b> (c1)	 Simulation result: <b>Success</b> (d1)	 Simulation result: <b>Success</b> (e1)
	Open bottom drawer	 Simulation result: <b>Failure – Shoulder joint limit</b> (a2)	 Simulation result: <b>Success</b> (b2)	 Simulation result: <b>Failure – Shoulder &amp; Wrist joint limit</b> (c2)	 Simulation result: <b>Success</b> (d2)	 Simulation result: <b>Success</b> (e2)
Drawers below desk	Open top drawer	 Simulation result: <b>Failure – Shoulder joint limit</b> (a3)	 Simulation result: <b>Success</b> (b3)	 Simulation result: <b>Failure – Shoulder joint limit</b> (c3)	 Simulation result: <b>Success</b> (d3)	 Simulation result: <b>Success</b> (e3)
	Open bottom drawer	 Simulation result: <b>Failure – Shoulder &amp; Elbow &amp; Wrist joint limit</b> (a4)	 Simulation result: <b>Failure – Wrist joint limit</b> (b4)	 Simulation result: <b>Failure – Shoulder &amp; Elbow joint limit</b> (c4)	 Simulation result: <b>Success</b> (d4)	 Simulation result: <b>Success</b> (e4)

VII. CONCLUSIONS

The present paper proposes a framework that performs automatic simulated accessibility testing of designs in virtual environments using a new user

modelling technique. The great importance of such a framework lies to the fact that it enables the automatic accessibility evaluation of any environment for any user by testing its equivalent virtual environment for the corresponding virtual user.

## ACKNOWLEDGMENT

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# Java Micro Edition Accessibility Framework

JME A11y API for mobile devices

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**Abstract—This paper analyses the design and architecture of the JME Accessibility framework indicating the appropriate implementation solution.**

**Keywords: Accessibility, API, mobile, devices, design, architecture, TCP/IP, events, notifications, accessible, messages.**

## I. INTRODUCTION

This paper points out the technical issues that have to be considered while the development process of accessibility framework will take place including platforms, tools and Java Virtual Machines. This work is partially being held in the context of the AEGIS IP project (Open Accessibility Everywhere: Groundwork, Infrastructure, Standards; <http://www.aegis-project.eu>) of the 7th European Framework Programme seeks to determine whether 3rd generation access techniques will provide a more accessible, more exploitable and deeply embeddable approach in mainstream Information and Communication Technologies (ICT).

This paper describes the architecture of the Java Micro Edition (JME) Accessible framework and depicts the JME software layers by introducing possible difficulties for the development process of the Accessibility Mobile framework.

It mentions concisely the implementation approaches which were considered during the design phase of JME Accessibility framework and analyses the types of messages (notifications) will be provided by the accessible custom graphical user interface (G.U.I.) components.

## II. ACCESSIBILITY FRAMEWORK

A software framework is defined as “an abstraction in which common code providing generic functionality can be selectively overridden or specialized by user code providing specific functionality” [1]. A framework is a special case of software libraries that they are reusable abstractions of code wrapped in a well-defined API; yet they contain some key distinguishing features that separate them from normal libraries. One of the AEGIS intentions is to provide the accessibility framework for mobile devices as an open source product so that developers can extend and modify its code. The framework will be delivered in the form of the following software modules:

- Suite of (standalone) applications; some of the framework's features will be provided as “applications”. By application it is meant that these modules will be totally independent in the aspects of execution life cycle and they will reside on top of JME technologies in order to be compatible with existing devices in the market.
- Application Programming Interfaces (API(s)). The qualifications of the Mobile Accessibility Framework will be accessed via Application Programming Interfaces. The API will contain operations that can inherit and/or override accessibility capabilities, such as big size fonts, operations that can be used by applications in order to send information to an assistive technology application and operations that can be used by assistive technologies. An assistive technology application registers as an accessibility event listener.

- Custom User Interface components, based on existing components. Accessibility User Interface components will be built in order to be used by developers. These UI components will be customized items that can be easily used by software developers within existing Integrated Development Environments such as NetBeans and Eclipse.

### III. LOCATION OF FRAMEWORK

This chapter describes the view map of implementation layers and analyses the possible locations of the mobile accessibility framework. The architecture of the built-in accessibility framework for mobile phones is dedicated to JME platform. The following figure depicts the division of the JME software layers in lower and higher layers. Different approaches for the building and the porting processes will be used for each of them.

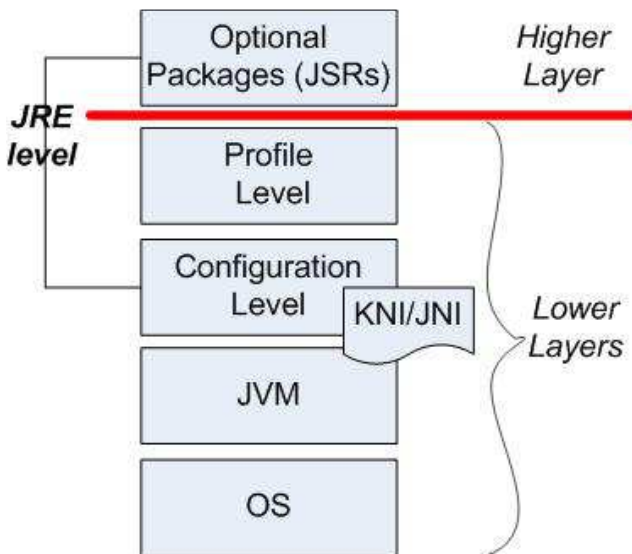


Figure 1. JME software Layer Levels

#### A. Lower Layer

Development in these layers needs to take into consideration the port of several important issues such as Central Processing Unit (CPU) and Operating System (OS). A porting effort for Java Virtual Machine (JVM) and Configuration will require building out of the box for study and evaluation, modifying the source code, makefiles

and build environment to suit the new product, tuning and rebuilding the implementation numerous times. Moreover, the tools which are available for software bundles in that layer is intended to individuals or companies that want to port the Connected Device Limited Configuration (CLDC) HotSpot Implementation Virtual Machine and the CDC (Connected Device Configuration) HotSpot Implementation to a new platform.

#### B. Higher Layer

The higher layer can be thought as the “Application Layer” which stands on top of existing platforms. Developing in that layer can avoid incompatibility and portability problems among different device technologies. The outcome will be a group of totally independent applications which reside on top of existing platforms and they do not rely on different device features such as OS and CPU.

In addition, there are many JME existing emulator platforms which can run either as standalone or integrated within Integrated Development Environments (IDEs) such as Eclipse and NetBeans. Thus, the applications will be built, executed and validated in those tools before the developer download then in the real devices. Some of existing mobile emulators for CDC and CLDC are Sony Ericsson CDC Platform UIQ SDK, Nokia Series 80 SDK, crème VM, S60 5th Edition Nokia (v. 1.02), Samsung, BlackBerry (JDE 5.0.0), LG, Motorola (MotoDEV).

### IV. ARCHITECTURE

In order to build the architecture for the accessibility framework for the mobile devices, we took into account existing technologies and their various specifications. Specifically, the existing APIs and their sample applications have been surveyed [5]. Such APIs were investigated are Java Accessibility API, ATK Accessibility Toolkit from Gnome's GTK+ project, Android Accessibility API, BlackBerry Accessibility API and iPhone Accessibility API.

The general concept was followed is that the accessible events have to be provided to assistive device applications such as screen readers or text to speech applications. The information will be closely related to the accessible application and it can be a textual description of a component. Furthermore, the

accessibility service has to run in the background and receives notifications/events by the system or a mediator mechanism which may be hosted by the system, when an accessible event is fired. Such events denote some state transition in the user interface (for example, the focus has changed or a button has been clicked). Analytically, the following three concepts participate in the overall architecture:

- Accessible application. It is the application containing accessible features such as accessible components, e.g. Accessible TextField.
- Accessibility Bus. It is the Event (Server) bus which receives notifications/events from accessible applications and distributes them to assistive technology applications.
- Assistive Technology (AT) applications. They are the software applications which serve the corresponding output to end-users, such as a screen reader or text to speech output. Initially, any assistive technology application should be registered to Accessibility Bus.

The following figure shows schematically the three parts.

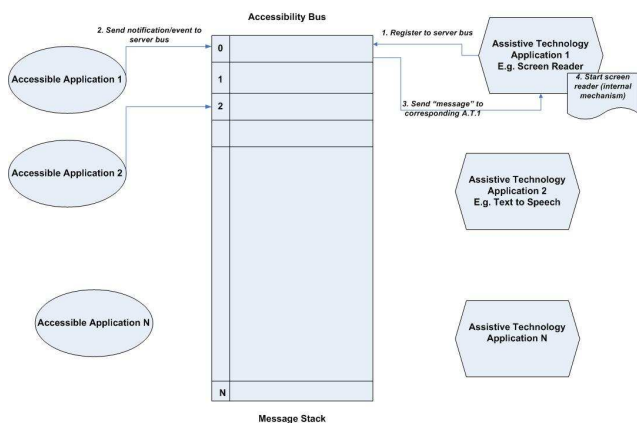


Figure 2. Schematic representation of architecture

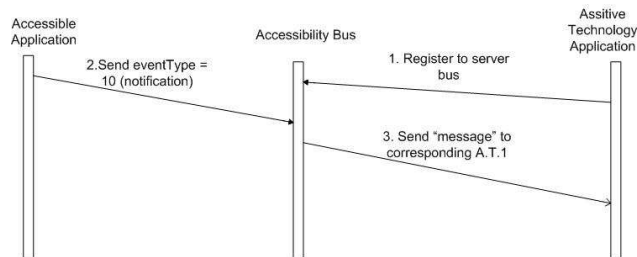


Figure 3. Interaction diagram

### A. Implementation approaches

Three different and possible approaches were thought and each of them was analysed in the “Built-in accessibility framework for mobile devices” AEGIS document [9]. These approaches are:

- Programming with TCP/IP (socket programming)
- Programming with Listeners
- Programming with native interfaces (JNI and KNI)

In all cases, the assistive technology applications will always run and listen for notifications.

However, it was decided to focus in the TCP/IP implementation approach<sup>4</sup> due to the reason that the assistive technology vendors have to spend limited resources (cost and time) in order to provide additional software modules which will interact with the Accessibility (Event) Bus.

This approach was successfully demonstrated during the last AEGIS project’s plenary meeting in order to prove the concepts and the entities described in the above JME Accessibility framework architecture.

## V. NOTIFICATIONS/MESSAGES

The general concept is that an AT application will be notified when accessible information is available. This can take place when a custom User Interface component changes programmatically or by user interaction and the assistive technology application receives that type of message regarding this change.

<sup>4</sup> All the above implementation approaches were analyzed in detail in AEGIS official deliverable “Built-in accessibility framework for mobile devices” [9]. This paper does not intend to compare these approaches and thus, it does not explain the advantages of the TCP/IP approach in detail.

The notification about the change may contain the following information:

- name of the custom User Interface (U.I.) component;
- type of event, for example, the contents of the custom UI component changing or the custom UI component getting focus;
- value of the custom UI component before the event;
- value of the custom UI component after the event.

For example, consider a CLDC or CDC device application that uses a custom class called `myTextField` that extends the `TextField` class. When the user changes the text in a `myTextField` instance, an AT application receives a notification and retrieves information about the text that the user changed.

Furthermore, the following changes to a UI component can trigger a notification to an AT application [4]:

- a change to the position of a cursor;
- a change to the name;
- a change to the text;
- a change in a child component;
- a change in the state;
- a change to the numeric value.

In addition, each UI component can have one or more states [4]:

- focused;
- focusable;
- expanded;
- expandable;
- collapsed;
- selected;
- selectable;
- pushed

Finally, some rules for supporting accessibility in order to make an application to work consistently

with AT will be taken into account [8]. These rules are the following:

- If a component does not display a short string, a descriptive name for it has to be specified.
- A tool tip for each component has to be set whenever it makes sense.
- If a tool tip for a component cannot be provided, a description alternatively can be provided that assistive technologies can give the user.
- Specify keyboard alternatives wherever possible and keep in mind that keyboard alternatives varies by components
- Assign textual description to all Images and Icons objects in your application.
- In a bunch of components that form a logical group, try to put them into one container.
- Any custom component is created, it should support accessibility.

## VI. ACCESSIBLE USER INTERFACE COMPONENTS

A draft version of accessible user interface components has already built and demonstrated successfully in AEGIS October's 2010 plenary meeting. These components were built for both CLDC and CDC device configurations in two different Graphical User Interface libraries (G.U.I.) for each of them. These accessible components were created and evaluated on the TCP/IP implementation approach.

### A. CLDC components

Two different suites of CLDC components were created. One suite was built with the use of LCDUI (`javax.microedition.lcdui` package) and the other one with the LWUIT library.

The LCDUI accessible components are custom components and extend the `javax.microedition.CustomItem()` class. They support operations such as the "getters" and "setters" of title, text, `editableText`, value, role and state properties.

On the other hand, the components were created on LWUIT library implement an accessible interface. This accessible interface defines methods

such as name, role, text and similar properties to the above in LCDUI's accessible components.

AEGIS aims to provide accessible custom graphical user interface components in both LCDUI and LWUIT libraries.

### B. CDC components

The CDC components are not yet implemented. However, their implementation will be based on both AWT (java.awt) and Swing (javax.swing) libraries. The design process of them has already taken place and it will be based on the aforementioned LWUIT's approach; an accessible interface will be used by each accessible component.

Their development and finalization of CDC and CLDC accessible components is expected to take place within the next year.

Finally, it was decided that the following accessible items will be delivered by AEGIS for both CDC and CLDC configurations on AWT, Swing, LCDUI and LWUIT libraries respectively:

- AccessibleLabel (AccessibleString Item)
- AccessibleTextField(EditableText)
- AccessibleDateField
- AccessibleText(Area)(EditableText)
- AccessibleCommand (Button)
- AccessibleTable
- AccessibleHyperLink

The above items will listen on various events (user's interaction) such as `keyPressed()`, `keyReleased`, `keyRepeated`, `pointerPressed()` (for the case a touch screen is provided by the mobile device), `pointerRepeated` and `pointerDragged()`.

### C. Accessible items in existing IDEs

Accessibility User Interface components will be built in order to be used by developers. These UI components can be easily used by software developers. AEGIS's intention is to provide these custom-made components within existing Integrated Development Environments (IDEs), such as NetBeans and Eclipse. The developer will be able to

easily drag and drop an item in the Screen Designer Form as it is shown in the above figure.

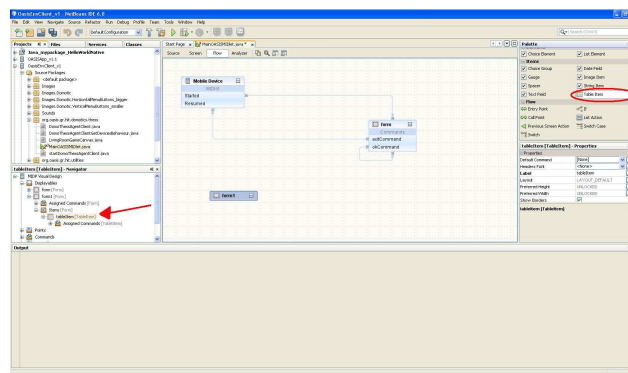


Figure 4. Custom TableItem within NetBeans IDE

The developer community will be capable to modify the source code of these custom items in order to enhance their features.

## VII. CONCLUSIONS

This paper provides an illustration of concepts that will participate in the system architecture such as the Accessible Application, Event (Server) Bus and the Assistive Technology Application. The interactivity between them has been also shown.

The design and the implementation phase focus on the higher layer of JME which is considered as the "Application Layer" of the OSI-Layer model. In that layer, the accessible application, the Accessibility Event (Server) bus and the AT application will be independent applications and they will be built and run on top of existing Operating Systems and (Java) Virtual Machines. These applications can be tested over existing OS and JVMs, existing device configurations and profiles without worrying about compatibility issues. Moreover, existing device simulator tools are available in order to test and verify them.

The TCP/IP approach has been currently approved and verified in Symbian OS devices. It was successfully demonstrated on Nokia N82 and Nokia N97 mini models. This approach is the most flexible, openness and portable solution and it can be applied easily to existing assistive application technologies and also to existing device models in the market. The assistive application vendors can extend existing technologies with the minimum possible cost and effort in comparison with the other

two solutions. Afterwards, the final version of AEGIS Accessibility Mobile Framework can be exploited and published as a Java Specification Request (JSR) following the specific Java Community Process standards.

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# Fall Risk Assessment in Ambulatory Monitoring

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**Abstract**— In the field of ambulatory monitoring of elderly, a lot of applications are focusing on the detection of emergency conditions, including falls. Although a clear societal benefit exists, much less attention is paid to ambulatory monitoring methods for fall prevention. On the other hand, in sports, fitness and rehabilitation, sensor based methods exist for the monitoring of gait and physical activity. One of the variables often used in those domains is energy expenditure, calculated from a tri-axial accelerometer. In this study, we investigate the test-retest reliability of accelerometer based energy expenditure, restricted to walking on a straight line at self-selected speed. Moreover, it is shown that energy expenditure during walking differs significantly between a group of elderly fallers and a group of elderly controls and correlates well with walking speed. This suggests that ambulatory and long term assessment of fall risk is feasible based on the calculation of energy expenditure during walking.

**Keywords**- *open accelerometer, energy expenditure, gait analysis, fall risk*

## I. INTRODUCTION

Falls are an important cause of hospitalization and of deterioration of the quality of life in elderly. Among people aged 75 or above, 32 to 42% was found to fall at least once a year [1]. Among elderly suffering from dementia, 66% experienced at least one fall a year. Falls lead to injuries, to a decrease in the quality of life and to an increased fear of falling,

which in turn increases the risk of falling [2]. In a recent study [3], it was shown that of 110 subjects (> 90 years old), 60% had at least one fall during the one-year study period. 80% of these fallers could not stand up independently after the fall. 95% of the fallers had an alarm system with a panic button, but 80% of the fallers having an alarm system, could not activate it after the fall event. This resulted in 30% of the fallers remaining on the ground for longer than one hour. Hence, panic buttons for alarm generation after falls have their limits. Automatic monitoring systems for fall detection exist, including accelerometers and camera systems. Accelerometer based systems depend on the correct wearing and handling of the sensor by the elderly. Camera based systems on the other hand are currently mainly experimental.

Given appropriate screening mechanisms, people with an increased fall risk could seriously benefit from the appropriate interventions, including changes in the prescribed drugs, exercise therapy, the prescription of walking aids, etc. [4]. Multifactorial intervention studies show a reduction of the falls by 25% to 40% [5,6,7]. The clinical assessment of increased fall risk typically involves careful observation of the postural stability and gait quality as for instance expressed by a score on the Tinetti [8] scale or by timing of specific exercises, e.g. the Timed Get Up And Go Test (TUGT) [9]. Both the Tinetti and TUGT test have good predictive value, but also have limitations: they should be administered by a specialist in the hospital and are based on a single assessment in time over very short walking episodes. Moreover, there is a debate on the



exact cut-off values for both tests[10] and both tests fail to identify subtle changes in the gait pattern at the onset of more easily observable major gait disturbances.

In clinical gait analysis, force plates, accelerometers, gyroscopes and other devices have been used to assess fall risk. Although more subtle changes can be identified in this manner [11], fall risk assessment is based on a single measurement of a short walking trajectory, in the hospital under the control of a gait specialist. There are clear benefits of detailed gait analysis under laboratory conditions for diagnosing and monitoring specific gait deficiencies, but we believe that in particular for fall risk assessment, long term monitoring of the gait pattern under natural walking conditions can provide important information. Typical features calculated from the accelerometer with known relevance in predicting fall risk in the clinical setting include postural sway, walk speed, stride length and stride width and measures capturing the global regularity of the walking pattern, including step and stride symmetry and regularity. However, these features are typically not calculated in a long term ambulatory monitoring setting at home.

On the other hand, currently there exists a wide spectrum of accelerometer based devices for long term ambulatory monitoring of step count and energy expenditure, as part of various programs for stimulating a healthy lifestyle and increased physical activity levels among the general public, but also focusing specifically on elderly. Such sensors provide a global estimate of total energy expenditure per day, but also detailed information per minute. Typically a two step algorithm is used to calculate activity related energy expenditure: a classifier is used to discriminate between several classes of physical activity (e.g. walking, sitting, running ...). For each of these classes, regression equations are used to relate features from the accelerometer signal to AEE. The validity of this type of monitoring has been investigated by means of comparison with the double labeled water test (e.g. [12,13]).

It is well known that regular physical activity is a crucial aspect of a healthy lifestyle, that inactivity is a risk factor for many diseases and that even small increases of physical activity can reduce risks. Also, it is known that energy expenditure and physical

activity decline with age [14,15] and that elderly with low physical activity are at greater risk of mortality than others [16].

Our long term vision is that such ambulatory monitoring devices currently employed for the assessment of physical activity levels and energy expenditure, could eventually also be used for fall risk assessment. Although we believe that long term home monitoring of gait is feasible and provides added value compared to short term monitoring in a clinical setting, there are two main challenges:

1. it is unclear whether the features currently calculated from the accelerometer signal in well controlled environments will prove to be valid and repeatable for assessing fall risk in uncontrolled settings.
2. Moreover, features are typically calculated offline, after the data recording and on regular desktops. Ambulatory monitoring would require on line calculations on the wireless device with limited processing power and memory.

In this paper, we want to investigate whether the energy expenditure during walking, calculated using a tri-axial accelerometer is relevant for fall risk assessment of the elderly. We show that energy expenditure during walking calculated from a short trajectory under clinical settings has high inter and intra rater reliability, that energy expenditure during walking is significantly different between young controls, elderly controls and elderly with increased fall risk and that energy expenditure during walking calculated from the accelerometer signal correlates very good with walking speed. These initial experiments act as a baseline for comparison with further studies on energy expenditure during unconstrained walking over longer periods of time.

## II. METHODS

### A. Subjects

Forty elderly ( $\geq 65$  years old) with increased fall risk (EF) (history of falls and/or Timed-Get-Up-and-Go-Test  $>15$ s and/or Tinetti-test  $\leq 24/28$ ), 40 elderly without fall risk (EC) and 40 young controls (YC) participated. Young controls were students and personnel recruited at the university (aged 18-30),



elderly were visitors to the geriatrics day care centre of the hospital. All subjects gave their informed consent and the study was approved by the ethical committee of the university hospital.

Each of the three criteria for inclusion in the fall risk group is a very good predictor for fall risk in itself. By including subjects in the fall risk group when presenting any of the three criteria, the elderly control group is not biased with elderly presenting any gait related problems.

*B. Data collection*

All subjects walked 18m on a straight line wearing a tri-axial accelerometer at the sacrum. This procedure was repeated three times and the sensor was removed and replaced between each walk by a physiotherapist. Between each walk the trajectory information recorded on the SD-card of the sensor was transferred to the pc and the card was emptied. Two of the three trajectories were collected by the same observer; a third trajectory was collected by a second observer. The two observers for each subject were randomly selected from a set of three. The order in which the observers assessed the subjects was also random.

The sensor used was the DynaPort MiniMod (McRoberts, The Hague, The Netherlands), which has a sample rate of 100Hz and a range +/- 2g for each of the three axes.

*C. Signal processing*

Previous work on the calculation of energy expenditure based on tri-axial accelerometers is often based on activity counts. Assuming that activity related energy expenditure (AEE) among elderly with increased fall risk is mainly caused by walking (and the contribution to AEE of sports activities is minimal), a regression equation relating activity counts per minute to AEE per kg body weight per minute is then provided [17,18]. Specific equations have been reported for specific subgroups, including children [19]. However, the exact definition of an activity count is often not specified, due to commercial reasons.

An alternative is to consider the average activity level per minute and to relate this to energy expenditure. In a study by Van Hees [20] movement intensity (MI) was defined as the average vector

magnitude of the three bandpass filtered (0.2 – 10 Hz) orthogonal acceleration signals. Van Hees showed that activity related energy expenditure expressed in (J/kg/min) for walking could be obtained from movement intensity using a linear regression equation and that the model correlates well to AEE computed in a respiration chamber.

In this paper, average MI was calculated for each walking trajectory according to Van Hees [20]. In order to exclude bias from the gait initiation and gait termination, the MI was not computed during the initial two and the final two steps. Steps were automatically detected from the signal, based on the maxima before the zero-crossings in the forward acceleration signal, after applying a fourth order zero lag Butterworth low pass filter with a cut-off frequency of 2 Hz [21].

*D. Statistical Analysis*

Statistical analysis was performed using SPSS version 18. Intra and inter rater reliability for MI were computed using the intra class correlation coefficient ICC(3,1), the method error (ME) and the coefficient of variation of the method error(CVME) [22]. Method error is defined as the standard deviation of the difference scores between test and retest divided by the square root of two. The coefficient of variation CVME is defined as the ME divided by the average of the test and retest score, multiplied by 100. Group differences were assessed using ANOVA after testing for normality with the Kolmogorov-Smirnov test.

TABLE I. TEST-RETEST RELIABILITY OF MOVEMENT INTENSITY

		Movement Intensity
Inter Rater	ICC(3,1)	0.96
	ME	0.02
	CVME	6.86
Intra rater	ICC(3,1)	0.97
	ME	0.01
	CVME	5.64

### III. RESULTS

Average MI was 0.37(0.07) in the YC group, 0.28(0.06) in the EC group and 0.20(0.06) in the EF group. Differences between EC and EF are significant at the 0.01 level. Group averages are visualized in figure 1 which shows averages and standard deviations of MI for each of the three groups. Intra rater reliability (ICC 0.96, ME 0.02 and CVME 6.86%) and inter rater reliability (ICC 0.97, ME 0.01 and CVME 5.64%) of MI were very high, see table 1. MI correlates well with walking speed ( $r^2=0.84$ ), see figure 2.

### IV. DISCUSSION

All tangible results of UCD Phases 1 and 2, encompassing the ÆGIS Use Cases, Personas, application scenarios and conceptual models, have constituted the basis for the specific application scenarios and experimental plans that have oriented the evaluation of the 10 first prototypes of ÆGIS in the first round of evaluation, that took place from May 2010 until end of July 2010. This has been only the first of the three evaluation rounds that are scheduled in the project in the context of the iterative design and development character. This section describes in short the overall evaluation framework developed in ÆGIS, focusing on the first out of the three in total evaluation rounds scheduled in its context.

Using a tri-axial accelerometer at the trunk, average movement intensity is a good measure to discriminate between fallers and non-fallers (high intra and inter rater test-retest reliability and good discriminative power) is strongly correlated to walking speed ( $r^2=0.84$ ) and walking speed is known as one of the best predictors for fall risk. Very high inter and intra rater reliability (>95%) was observed under similar experimental conditions for walking speed (e.g. [23]).

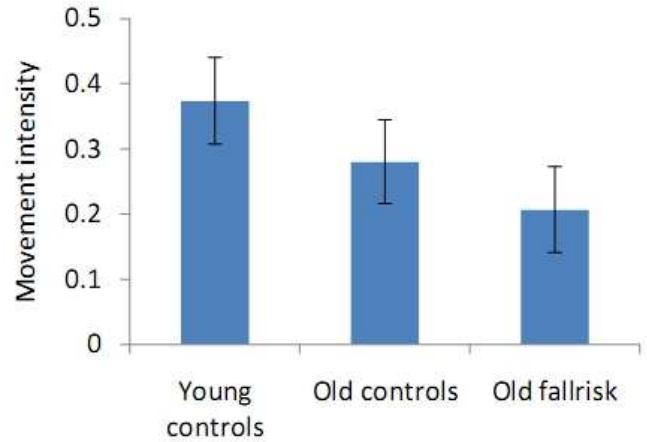


Figure 1: group averages of movement intensity (MI). MI is significantly different between OF and OC.

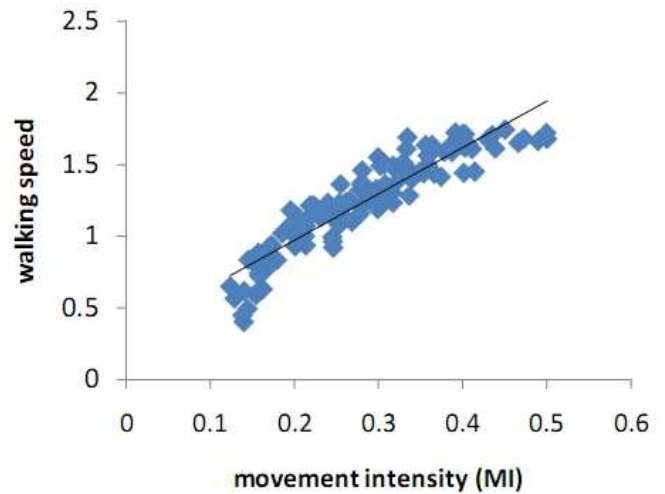


Figure 2: Movement intensity correlates well with walking speed.

The advantage of MI is that it can be calculated online on the device; whereas walking speed is more difficult to obtain in ambient monitoring settings. The distance walked (on which walking speed is based) can be obtained from integration of the accelerometer system, but this approach suffers from integration drift.

Given the positive results of this hospital study, we propose to calculate MI on the body worn sensor itself during long term monitoring of elderly at home in order to investigate whether long term fluctuations in MI do correlate with changing fall risk.

## V. CONCLUSION

High test retest reliability of movement intensity calculated from a tri-axial accelerometer worn at the trunk during walking at self selected speed is shown and it is shown that movement intensity is a good feature to discriminate between elderly with increased fall risk and elderly without increased fall risk.

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# Integrating Intelligent e-Services and Information Access for Elder People

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**Abstract—** The concept of the information society is now a common one, as opposed to the industrial society that dominated the economy during the last century. It is assumed that all sectors should have access to information and reap its benefits. Elder people are, in this respect, a major challenge, due to their lack of interest in technological progress and their lack of knowledge regarding the potential benefits that information society technologies might have on their lives. The Naviga Project (An Open and Adaptable Platform for the elderly people and persons with disability to access the Information Society) is an European effort whose main goal is to design and develop a technological platform allowing elder people and persons with disability to access the Internet and the Information Society. NAVIGA also allows the creation of services targeted to social networks, mind training and personalized health care.

**Keywords-** *e-health, disability, Internet, elder people.*

## I. INTRODUCTION

Today, developed countries have great difficulties with effective health services and quality of care in a context marked by the population's ageing. This trend, as seen in Figure 1, has dramatic effects on both public and private health systems, as well as on emergency medical services, mainly due to an increase in costs and a

higher demand for more and improved benefits for users, as well as for increased mobility.

This demographic change will lead to significant and interrelated changes in the health care sector and technologies promoting independence for the elderly population. As representative data, approximately 64% of the European population is made up of 20 to 64 year olds, while the 65 and over group covers 17%. Thus, there are some 4 working employees to every pensioner. On the other hand, it is estimated that the 20 to 64 year old group will decrease to 55% and the over 65 will increase to 28% by the year 2050, making the proportion 1 to 2 instead of 1 to 4. Spending on pensions, health and long-term care is expected to increase by 4-8% of the GDP in the coming decades, with total expenditures tripling by 2050.

People live longer in developed countries as a result of better living and health conditions. For example, in North America only 4.5 % of population over 65 years old lives in nursing homes, a percentage that has decreased in recent years.

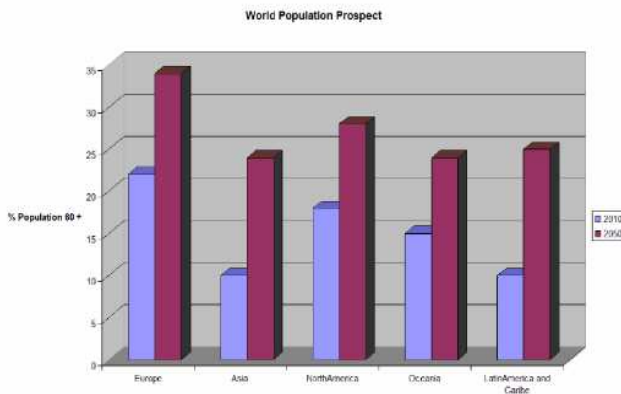


Figure 1. Demographic change according to the foresight of the United Nations, <http://esa.un.org/unpp> (access: 06/12/2010)

The elderly population is constantly prepared for to age better due to a decrease in disability, resulting in the elderly being more active in their daily lives. Despite the improvement in conditions for coping with ageing and an increasingly active lifestyle, there are obvious changes that occur in behaviours and skills during the latter part of life.

These changes may include decreases in social relations and physical abilities, loss of memory, comprehensive and cognitive functions. Previous studies have shown that the ageing process is accompanied by a decrease in neuro-motor and cognitive functions. Compared to young people, the elderly's demonstrate poor performance on tests, including reaction times, motor coordination, short-term and complex or abstract conceptualization. In general, these changes result in a decline in the quality of life of for the elderly.

There are also studies showing that a decrease in neuro-motor and cognitive functions in the elderly's can be accelerated by disuse or simply by a decrease in activities that require frequent cognitive processing. Specifically, it has been shown that the central nervous system retains a significant amount of plasticity or neural flexibility with age, and through mental training exercises, this neural flexibility may be kept in good condition over time.

Another important impact that can be seen particularly in persons living in nursing homes is boredom. Participation in social activities does not necessarily improve this feeling and sometimes creates negative attitudes in participants, although

activities based on individual preferences can have positive effects and help to overcome boredom, increasing the quality of life for elders. It is a challenge finding innovative activities that involve the elderly and encourage them to keep practicing with the activity. An adequate understanding of the disuse of motor and cognitive functions can help to prevent the decline in these skills and participation in activities based on individual preferences can reduce boredom. There is a real need for activities that address these two concepts, and these activities may be none other than mental exercises specially designed for elderly's.

The current trend is to improve the quality of life of older people not only extend the lifetime, the "gerontechnology" [1] is a very active discipline focused on improving the lives of elderly's, considered as a special group of users whose particular skills and needs in social and cognitive levels should be taken into account during the design process of any technology solution focused on this group. We must also consider that older people often do not feel comfortable in handling a computer and the use of technological devices seems complicated for them. This problem may be worse considering the decline in cognitive, visual or motor abilities.

The Naviga project (2009-2012) is an European initiative funded by the Eurostar [2] R&D program and whose main objective is to provide these collective tools, devices and methods to enjoy personal autonomy and a better quality of life, to do that, within the project we are developing an integrated technology platform to provide Internet access through a computer or TV. In addition, the proposed platform will facilitate the incorporation of elderly's and people with different functional capacity to the Information Society through the use of special devices, social networks, and applications to improve the cognitive ability or personalized health services.

The consortium comprises five SMEs conducting research (investment min. 20% of annual turnover in R & D), a university and two end users (an hospital and a daily health centre located in Madrid region ) also involved in the project.

## II. OBJECTIVES OF NAVIGA PROJECT

The Naviga project, through the use of information and communications technology, intended to cover a range of social and health objectives aimed to improving access to Information Society by the elderly's and people with disabilities. Within Naviga we will develop an open platform and adaptive technology for two purposes:

1) On the one hand, the development of an adaptive communication interface between user and computer or television, to facilitate the understanding of Internet and new information technologies to people with a low-tech, while encouraging its use by providing a simple and friendly human machine interface. Also, this interface takes into account the integration with different support products on the market to ensure that users can use those techniques.

2) Furthermore, the development of a platform that allows rapid creation of services and applications specifically for the elderly and disabled people with a common API to ensure integration with friendly interface above mentioned and provide a similar look to all developments.

The main social objectives lies in the attempt to bridge the gap that prevents the elderly's and people with disabilities access the Information Society. To do this, we are developing simple mechanisms for interaction between technical elements (computer, television, product integration support for access), and people:

- A Web browser that integrates simple mechanisms of interaction and to improve usability through the use of alternative hardware to keyboard as for example voice commands. Also, the browser must be compatible with the common support and aid products for elder people.
- Development of social networks among people with the same disability, where users can find people with common interests and concerns, and share information, experiences and advices. An example would be evaluate and recommend support products, as these aids often have a high cost and does not respond equally to all profiles of disability.

Similarly, the Project will provides a range of health-oriented goals that help elderly to keep active through mental training exercises, and otherwise assist staff medical (hospitals, health centres) in monitoring the treatment of these people from homes:

- Developing services and games that allow mental training (mind training), suggesting exercises to keep the mind active, and getting people to communicate and participate to a greater extent in their social community. This will prevent premature degeneration of mental activity, and improves the mood of older people with functional diversity by increasing the feeling of being useful to society around them. Although little is known about the perceived benefits of digital games for the elderly, there is a small but growing body of research evidence in support of the notion that digital games can have a significant positive impact on the elderly's mental and physical health and wellbeing [3]. Some research [4] has showed the benefits of gaming for elderly people in several domains: stimulation of social interaction and participation; enhancement of perceptual-motor skills (eye-hand coordination, dexterity, and fine motor abilities); improvement of performance speed (basic movements and reaction time); information processing, reading, comprehension, memory, self-image, etc. and transfer of the skills acquired in the games to other aspects of everyday routine like automobile driving.
- Development of personalized health services, such as warning and reminder system for medication adherence through an automatic smart pill dispenser or rehabilitation physiotherapy through virtual reality applications. In the latter case, the main objective is to recover the functionality of the hand of patients using a glove that makes measurements of the angles of each phalanxes of up to 22 degrees of freedom with high accuracy. The device uses a strain sensing technology that transforms the movement of the hand and fingers to digital data in real time.



### III. ARCHITECTURE OF TECHNOLOGY PLATFORM

The technology platform being developed within the Naviga Project, see Figure 2, must solve two major technical challenges:

- Firstly, the connection to the platform in an interoperable way of different support products and communication interfaces, integrating health monitoring devices that generate medical alerts, fall detection systems and security alarms, and devices that enable accessibility to users with motor or cognitive disabilities to information and entertainment services, and advanced communications such as videoconferencing. The number of support products available in the market is very high, but often not compatible with each other or have the same degree of utility to different users who share a disability. It is therefore necessary to develop a common multi-modal interface that simplifies the integration between computer and any specific support product. It should also be taken into account the need for multi-channel access, allowing Internet access through the computer, television or mobile devices.
- Second, the development of a set of tools for creating and deploying services and applications to ensure compatibility and rapid integration of new services and devices on the platform, while providing a common adaptive and easy to customize interface for user interaction.

It is very common at the end of a project that maintenance and integration of new services disappear. The Naviga project aims to simplify the integration of new services and applications within the platform using freely available technologies that allow the subsequent adaptation of the code easily, so can still be used for further developments.

Among the initial services of the platform, there are technical difficulties related to the application area. For example, the development of an accessible Web browser must be multimodal and interoperable in order to take into account the needs of all members of the group, which greatly complicates the solution given the diversity of users. Also, the use they make of the social network can be very

different, both, use objectives (social relationships, share experiences, recommend support products) and access to services, must

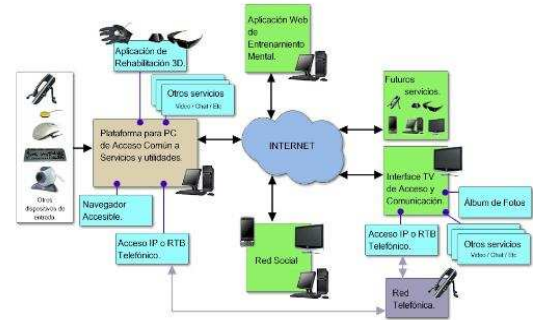


Figure 2. Diagram of Naviga Architecture Technology Platform

provide simple user interfaces, easy to use and highly adaptability to the preferences and characteristics of each person.

One of the highlights of the project is covered by many health aspects (tele-assistance, accessible navigation, social integration, cognitive stimulation, management treatments) from a single, integrated and open platform. Previous projects in this area dealt with a single field with a much narrower approach, developing closed systems specific to a limited number of devices. Naviga unified design ensures a common interface for all services, and their complete integration with control and measuring devices, the communications network and support products for user interaction with the system.

NAVIGA platform provides an open system based on SOA (Service Oriented Architecture) that enables and facilitates the development of new applications and services that seamlessly integrate with existing modules without need of an expert knowledge of the lower layers architectures and languages. Also, open source implementation based on Java EE and scripting languages like JavaScript, and compliance with accessibility standards of the ISO and the recommendations of the WAI, ensure continuity of service and support the development of the platform.

Designing the platform in conjunction with the devices ensures optimum performance and response to user actions, as adapted interaction mechanisms must play sometimes very complex tasks from very



simple input actions. The end-user participation in the project to determine more accurately their needs and desired objectives, and prototype validation during the development process in aspects as interface usability and effectiveness of associated devices, verifying compliance with the requirements.

#### IV. EXPECTED RESULTS

As mentioned above, from the point of view of development, the project's expected results are:

- A hardware interface device adaptable to all seniors and people with disabilities enabling the interaction with computer or television.
- A framework (tools and methods) for creating and deploying services and applications.
- The development of services including a Web browser that allows access for elderly's and disabled people to the Internet.
- Two technology demonstrators in the field of e-Health and entertainment.
- An analysis of business opportunities and business requirements (identifying their strengths and weaknesses) for the successful commercialization of project results.

During the running of Naviga project two case studies /scenarios will be implemented, to demonstrate the functionality of the framework developed. One dealing with rehabilitation at home based on virtual reality, while another scenario will be developed and evaluated in a care centre for elderly's and people with disabilities aiming their access to the Information Society through the Web browser and in particular social networks and

mental training. The scenarios will have real participation of end users to validate the technological advances.

#### ACKNOWLEDGMENT

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# Improving the Quality of Life for Elderly by Adapting to Each Specific User

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**Abstract—** This paper presents the Confidence system, which aims to prolong independent life of the elderly. It accomplishes this with a set of intelligent modules that recognize falls and general disabilities, and inform the emergency services when a hazardous situation is detected. This way the elderly do not require constant caregivers' monitoring and are not forced to leave their homes since they are confident that they will receive assistance when needed. The Confidence modules adapt to each particular user by initialization before the first use. The initialization requires recordings of several user activities. The results show that the accuracy of the system significantly increases if the modules are properly initialized.

**Keywords-** Confidence, elderly care system, fall recognition, general disability recognition, adaptation to the end user, active learning

## I. INTRODUCTION

The percentage of elderly people in the modern societies is rapidly increasing. Consequently, the request for caregiver assistance and its costs are also increasing. Nevertheless, the elderly people would prefer to live an independent life without a need for such assistance, but they raise a concern that nobody could help them in case of an accident or a sudden health problem. A solution would be to create a caregiver system that is less expensive and more efficient than a caregiver assistance, and enables an independent life for the elderly.

An efficient caregiver system has to monitor the elderly 24 hours a day and has to be non-intrusive to

enable independent life at home [1]. In order to develop such systems, the main problems limiting the independent life of the elderly have to be identified. Such problems range from a large set of possible illnesses to the falls as a consequence of deteriorated motor abilities. An efficient caregiver system has to detect falls and discover various illnesses or general disabilities. When such states are discovered, the system has to report them to an emergency center, a caregiver institution or a hospital. Consequently, such a system does not completely replace the caregiver institution. Instead, it complements it and ensures that its limited resources are used effectively.

This paper presents the Confidence system, developed as part of the FP7 Confidence project [2], which aims to reduce the dependency of the elderly people on the caregiver institutions. It uses position and acceleration data from tags placed on the user's clothes in order to recognize falls and general disability. The recognition procedure is performed in three steps. Firstly, the input data has to be filtered. Next, the activity of the user has to be recognized. Finally, the falls are recognized using activity information, and general disabilities are recognized by finding deviations in the user's behavior. When events such as falls and general disabilities are recognized, an emergency center is informed that the user needs help.

In the real-world usage the Confidence system monitors only one person. Therefore, the system is adapted to the monitored person, which results in an increased accuracy. The adaptation is done during the system initialization and the system usage with active semi-supervised learning. In both stages

the built-in classifiers for activity recognition are updated with the user-specific data.

This paper is organized as follows. Firstly, the proposed caregiver intelligent system is presented. Secondly, the initialization procedure is described. Thirdly, the active semi-supervised learning for improving the activity recognition classifiers is given. Fourthly, the proposed methods are tested and the results are presented. Finally, the paper concludes with ideas for future work.

## II. SYSTEM ARCHITECTURE

The presented system recognizes falls and general disabilities using position and acceleration of tags attached to the user's clothes [3]. These input data are received from the Ubisense localization system [4] and acceleration system [5]. These systems process and send the data from four tags located on the user's ankles, chest and belt. When the system receives these data, it processes them, analyzes them, and produces an alarm if a fall is recognized, or a warning if a general disability is detected. These messages are sent to the user via a basic Portable device or an advanced Control panel on the computer screen. If the user does not cancel the alarm or warning, an emergency center is informed. The system modules and data flow are shown in Fig. 1 and described in the following sections.

### A. Preprocessing

The Preprocessing module receives the input data, i.e., position and acceleration data from the tags. The data from individual tags are not synchronized and neither are acceleration data synchronized with position data. Besides, the frequency of incoming data is not constant even for each single input system. Consequently, the input data has to be synchronized and the information about all the tags is combined into single snapshots. A snapshot stores the information about all tags, i.e., their positions and accelerations, at one moment in time. When a snapshot is created, it is passed to the Filtering module.

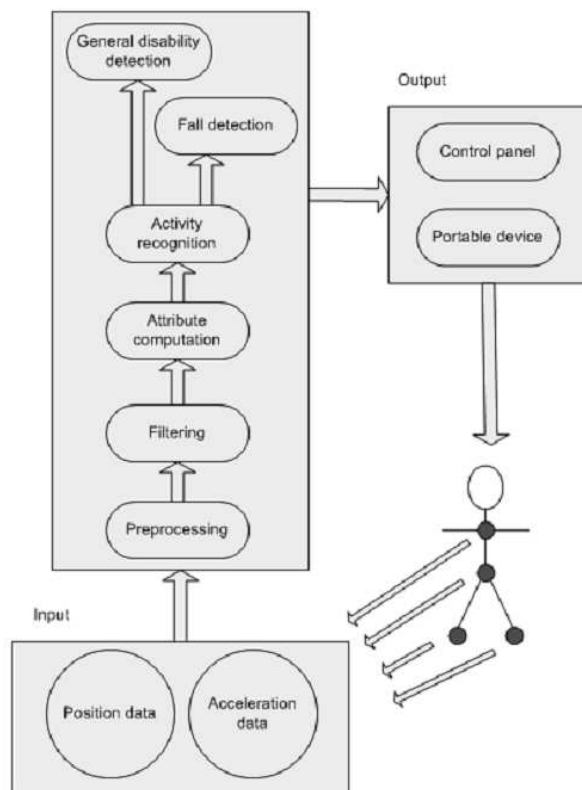


Figure 1. System modules and data flow.

### B. Filtering

The Filtering module is used to increase redundancy since the real input data may be inaccurate or even missing, e.g., a missing position of a tag. In order to bypass these shortcomings, the tags' data is filtered and smoothed using six methods. An example of such a method is the anatomic filter that uses anatomic constraints, e.g., the distance between the belt tag and the chest tag that is constant, in order to correct the positions of the tags. In addition, the data of missing tags are estimated using specific heuristic procedures. The output is a snapshot with no missing data and with positions and accelerations that are filtered and smoothed. A snapshot is then passed to the Attribute computation module.

### C. Attribute computation

The Attribute computation module calculates a set of attributes related to the human body and available tags, e.g., the speed of each tag and the distances between the tags, which are used by the successive modules. When the attributes are

calculated, they are added to the snapshot that is then passed to the Activity recognition module.

#### *D. Activity recognition*

The Activity recognition module recognizes the current user's activity. Examples of the activities are standing, sitting, lying, walking, standing up etc. In order to determine the current activity, two modules are used, namely Random forest classifier [6] and expert-knowledge rules [7]. Their classifications are combined into the final classification using heuristics. The final classification is smoothed with a Hidden Markov Model [8], which eliminates infeasible activity transitions, e.g., from sitting to standing without standing up in between. Afterwards, the assigned activity is added to the snapshot, which is passed to the two main modules: Fall detection and General disability detection.

#### *E. Fall detection*

The Fall detection module [9] recognizes falls and other potentially dangerous situations, and produces alarms. An example of such a situation occurs when the user lies immovable on the floor for a prolonged time. In order to recognize alarms, two methods are used, namely expert-knowledge rules and two classifiers trained by machine learning algorithms C4.5 [10] and SVM [11]. The two classifications are fused using heuristics.

#### *F. General disability detection*

The General disability detection module recognizes general disabilities and issues a warning. An example of a general disability is limping. A general disability is recognized by collecting a set of statistics about the user behavior, mainly walking statistics, and comparing them to the past statistics of the same person in order to recognize unusual or changed behavior. If the behavior change is significant, it may indicate the development of an illness/general disability. The changes are recognized using the LOF [12] algorithm.

#### *G. Control panel and Portable device*

When an alarm or a warning is produced, it is sent to the user, relatives and afterwards to an emergency center, a caregiver center or a hospital. The modules for sending alarms and warnings are implemented in the Control panel and Portable device user interfaces. Both interfaces also enable

cancelling an alarm before it is forwarded. The Portable device has a simplified interface that does not enable any other communication with the user. On the other hand, the Control panel has an advanced interface that also shows positions of the tags in the current room, a detailed explanation of the alarms and warnings, a video of the current situation in the room etc. In addition, it displays the history of alarms and warnings upon request. An important issue is that the user can define the protocol of sending warnings and alarms thus adapting communication according to his/her wishes.

#### *H. Initialization of the modules*

Since the system is used only by one user, the majority of the modules have the potential to work better if they are adjusted to that user either initially or during usage. For example, when the current activity is calculated, it is more appropriate to use user-specific machine learning classifier than a general classifier. Therefore, an appropriate initialization procedure is crucial for achieving high accuracy of the system. The implemented initialization procedure is described in details in the following section.

### III. SYSTEM INITIALIZATION

#### *A. Initialization procedure*

The purpose of the initialization procedure is to automatically adjust the parameters that are unique for each individual user and improve the accuracy and precision of the Confidence system. The procedure is introduced through a user-friendly interface Initialization Wizard, containing up to 11 steps. These steps can be divided into four sets according to their content. These sets are: (1) system connection and initialization of the modules, (2) basic user information, (3) activity recording, and (4) lying locations. A diagram representing the initialization procedure is shown in Fig. 2. During this procedure the system adjusts the machine learning classifier for activity recognition module by scaling values of certain attributes, calculates user specific expert rules for activity recognition module, creates personal machine learning classifier, and stores the data about the room. The following sections describe the initialization steps in details.

### 1. System connection and initialization of modules

First, the position and acceleration systems have to be installed and connected to the Confidence system. Second, the following modules in the Confidence system have to be initialized: (1) Preprocessing, where the raw data from the sensors are collected and prepared for further processing, (2) Filtering, where the data is smoothed and corrected with six filters, (3) Attribute computation, where all significant attributes for expert rule generator described in Section B and activity recognition machine learning classifiers are calculated. The acceleration data is not used in the adaptation process. Therefore, the acceleration system can be disabled during the initialization.

### 2. Basic information

In this step, the user provides information about him/her and his/her requirements. The system collects the following basic information. Firstly, the user has to identify himself/herself with a name or with an anonymous code. Secondly, the user height is stored for classifier adjustment. Thirdly, the user has to determine the time in the day when the collected statistics and possibly warnings are shown on the Portable device or on the User screen [13] if the user does not use the Portable device. Finally, the duration of the activity recordings has to be defined according to the user's ability to perform basic activities such as standing, lying and sitting. The activity recording is described in the following section. The default duration of a recording is 30 seconds. The user can choose to perform one activity for up to ten minutes.

### 3. Activity recording

The activity recording procedure consists of four to seven steps, depending on the vitality of the user. The user should be able to perform the basic activities: standing, sitting and lying. Additionally, more advanced activities are optional and can be recorded after the basic activities. These activities are sitting on the ground and being on all fours. The recorded data is used in order to improve activity recognition rules and the machine learning classifier thus increasing the accuracy of the entire system.

### 4. Lying locations

This step of the initialization wizard stores the lying locations for the current room where the system is installed. Lying locations are all locations where the user is allowed to lie (e.g., bed) or to perform activities that could be considered hazardous by the system (e.g., exercise and yoga). When the initialization procedure is completed, three files are created. The first file describes the general information about the user; the second file contains the new rules created as described in Section B and used in the Activity recognition module, while the third file contains the data for the personal machine learning classifier for the Activity recognition module. This module is used for active semi-supervised learning as explained in Section IV.

### B. Rule adaptation

The rule engine for activity recognition was originally created by the domain expert using the knowledge stored in a decision tree classifier and domain knowledge [7]. An example of a rule in the rule engine is as follows: "IF  $\text{coordinateZ}(\text{chest}) < 0.3 \text{ m}$  and  $\text{velocity}(\text{chest}) \approx 0$  THEN lying". However, this is a general rule not specialized for a specific user (body dimensions) and a specific room (e.g., low chair). The rules in the rule engine for activity recognition need to be adjusted to suite each particular user (e.g., to user's height and movement characteristics) as well as the particular system localization hardware in a specific room (e.g., adjustments to perform optimally given the hardware's noise level).

The adaptation of the rule engine encompasses only the adjustment of the limits in the conditions of its rules. In the example above, this would be the values 0.3 m (the z coordinate of the chest) and 0 (the velocity of the chest). The form of the rules stays unchanged as defined originally by the domain expert. Activity recordings obtained with the initialization wizard represent training data for rule engine adaptation. We considered two approaches for the adaptation of the limits in the rule engine: (1) a genetic algorithms and (2) an approach which computes information gain for each attribute included in a rule in order to determine the most suitable rule condition limit. Due to time constraints, the second approach was used for the adaptation of the rule engine during system initialization.

### C. Machine learning adaptation

The machine learning module contains the Default classifier for activity recognition that is created using position data of several users. Similarly to the rules module, the Default classifier may not be suitable for the current user since his/her height might be different with respect to the previously tested users. Consequently, this classifier has to be adapted during the initialization procedure as follows. The initial data has to be scaled by taking into consideration the height of the current user that is stored during the initialization procedure (Section

#### IV. ACTIVE SEMI-SUPERVISED LEARNING

In order to increase the accuracy of the machine learning classifier for activity recognition, a combination of the active learning method and semi-supervised learning method has been implemented. The idea of active learning is to improve the accuracy by choosing the data for the training set. The active learning method updates the existing classifier, namely the Default classifier, by taking into account the data that has not been included in the existing classifier (e.g., recent data gained after the classifier was created). The implemented method is based on the stream-based selective sampling method. The presented system receives the data from the tags and creates instances in real-time. The instance contains calculated attributes describing distances between tags, velocity of tags

IV.B.1). However, such minor adjustments of the Default classifier do not guarantee a high accuracy of the activity recognition module. Consequently, a more advanced procedure for the adaptation to the user has been designed as described in the following section.

In addition to the Default classifier, the activity recognition uses the Person classifier. This classifier is created by taking into account the data about the activities that are recorded during the initialization procedure as described in Section A.3.

and angles between tags. The activities of the instances are obtained with the Default and Person classifiers. In addition, the confidences of such classifications are also obtained. Since the classifiers may classify an activity into different classes, a new Meta classifier is created in order to select the most suitable classification. Afterwards, if the confidence of the classification is sufficient, the instance is used by the active learning method to update the existing Default classifier. A similar method to ours was used for video annotation [14]. Their method uses two complementary classifiers for the classification and the decision on the more suitable classifier is based on an effectiveness measure. If the effectiveness measure is higher than certain value, the video has to be labeled manually.

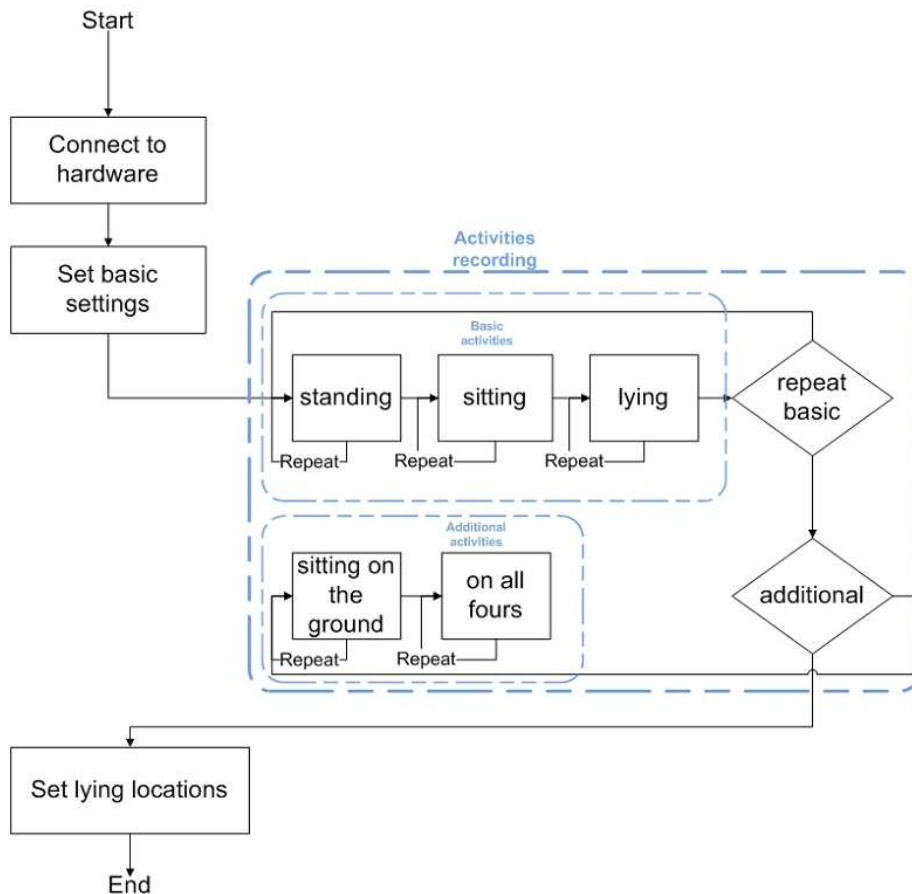


Figure 2. Individual steps within all four sets of the initialization procedure.

### A. Activity recognition classifiers and Meta classifier

This section describes the three classifiers, namely the *Default*, *Person*, and *Meta classifier*. The first two are classifiers for activity recognition while the last classifier chooses which of the first two should be trusted.

#### 1. Default classifier

The Default classifier is a generic classifier. It contains activity data from recordings of three persons. The activities that are recognized by this classifier are lying, standing, sitting, going down, standing up, falling, sitting on the ground, and on all fours. The classifier was built using the Random Forest algorithm. Afterwards, it was tested with leave-one-person-out cross-validation. The achieved accuracy was 86%. By examining the results we have learned that certain physical characteristics of a person can be significant for classifier accuracy.

One of these characteristics is the height of the person. In order to test how the user's height affects the accuracy, an additional person with a different height compared to the already tested persons has been tested and the accuracy has decreased to 73%. In order to overcome this shortcoming, the active semi-supervised learning method has been implemented that updates and adapts this classifier which resulted in increased accuracy (see Section V for the results).

#### 2. Person classifier

The Person classifier is user specific classifier that contains only three basic activities: lying, sitting and standing. Amount of the data representing each activity depends on the previously chosen time for recording the individual activity. Since the dataset is relatively small, each recorded instance is multiplied four times before the classifier is built with the Random Forest algorithm. In order to define the Meta classifier described in the following section, a



Person classifier was build and afterwards tested with a 30 minutes recording with labeled data of the current user. The achieved accuracy was 69%. The accuracy was low since the recording contains all eight activities while the Person classifier can classify only three of them.

### 3. Meta classifier

The Meta classifier is used to decide which of the previously mentioned classifiers is more appropriate for the classification of the current instance. It was built on two recordings with labeled data of the current user. The duration of each recording is 30 minutes. The attributes of the classifier are calculations that reflect statistical relation between the classifiers and attributes that include the classifications of the Default and Person classifiers. The actually used attributes were selected manually from three different sets of attributes after an extensive testing of several Meta classifiers. Each Meta classifier was tested with the ten-fold cross-validation. The tested sets of attributes can be seen in Table 1 while the accuracy of the tested Meta classifiers can be seen in Table 2. The results show that the most efficient set of attributes is the combination of the first and third set of attributes. The algorithm with the highest accuracy is Random Forest algorithm.

### B. Classifier adaptation

The adaptation procedure consists of four steps: 1) Default classifier scaling, 2) Person classifier creation 3) usage of the Meta classifier to label the instances and 4) Default classifier update if the confidence in the activity label is high. In case the fourth step is positive, the system updates the learning data for the Default classifier thus building a new classifier. The first two steps are done during the initialization procedure (Section III.A). The last two steps are implemented as the active semi-supervised learning that is done during the normal usage of the system. The entire process of the active semi-supervised learning can be seen in Fig. 3.

#### 1. Default classifier scaling

The height of the person is a parameter that significantly affects the classifier accuracy. Consequently, the Default classifier may not be efficient. Nevertheless, the data used to build this classifier, which are correlated to the height of the tested users, can be easily scaled to the current

user's height using the equation (1) where we calculate the ratio between the height of the current user ( $h_P$ ) and the average height of people ( $h_A$ ) whose data is contained in the Default classifier and multiply it with the old value of the attribute ( $attribute\_old$ ). Consequently, the accuracy of the updated Default classifier increases as presented in Section V.

$$attribute\_new = \frac{h_P}{h_A} \cdot attribute\_old \quad (1)$$

#### 2. Person classifier creation

The purpose of the second step is to capture the data of the basic activities of the user and create a new classifier for activity classification. However, this classifier is built considering only the data of the three basic activities while the Default classifier is built using the data of all activities. Consequently, the Meta classifier in general should use the Person classifier to classify three basic activities with higher confidence and accuracy, and the Default classifier to classify the other activities.

##### 1. Meta classifier labeling

The Meta classifier labeling is done as follows. Each instance that the system receives is classified with the Default and the Person classifier. In addition, both classifiers return the confidence values of the predicted classes. The attributes of the learning data for the Meta classifier are the predictions and confidences of the two classifiers, statistical attributes and attributes calculated with logical functions. The output of the Meta classifier is the index of the classifier that is more appropriate for the classification of the current instance.

##### 2. Default classifier update

The update of the Default classifier occurs only if the confidence of the classification that is chosen by the Meta classifier and the confidence of the Meta classifier are sufficiently high. More precisely, both parameters have to be 100% confident in order to use the current instance for the adaptation. Such instances are added to the training set of the Default classifier and after a certain time interval a new Default classifier is built. Consequently, the Default classifier is adapted to the current user during the classifier update procedure.

The classifier update using active learning procedure stops, when the Meta classifier chooses only the Default classifier during the last 30 minutes. When active leaning stops, only the Default classifier is used for further activity classification.

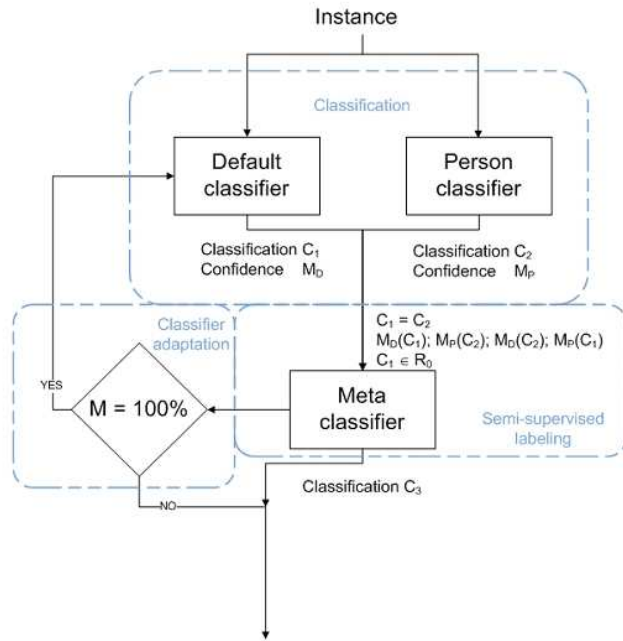


Figure 3. Active semi-supervised learning procedure assembled of classification, semi-supervised labeling and Default classifier adaptation.

TABLE I. ATTRIBUTE SETS

Set	Attributes	
	Attribute	Label/Equation
1	Default classifier classification	$C_1$
	Person classifier classification	$C_2$
	Default classifier confidence in $C_1$	$M_D(C_1)$
	Person classifier confidence in $C_2$	$M_P(C_1)$
	Is $C_1$ a basic class	$C_1 \in R_0$
	Are the classes equal	$C_1 = C_2$
2	z coordinate of all tags	/
	Distance in height between neck and average height of ankles	/
	Distance in height between neck and belt	/
3	Default classifier confidence in $C_2$	$M_D(C_2)$
	Person classifier confidence in $C_1$	$M_P(C_1)$

TABLE II. TESTED ALGORITHMS

Algorithm	Attribute set combination				
	Snapshot + 1	1	2	1+2	1+3
SMO	86.6%	92.9%	88.9%	87.8%	88.3%
C4.5	96.8%	95.4%	96.1%	96.6%	95.9%
Random Forest	90.9%	95.9%	96.6%	96.9%	<b>97.4%</b>
Naïve Bayes	61.0%	75.7%	70.1%	68.8%	82.3%
AdaBoost	88.6%	84.8%	84.6%	84.6%	79.0%
Bagging	96.9%	94.7%	95.8%	96.2%	95.8%

TABLE III. ACCURACY OF THE CLASSIFIERS FOR EACH ACTIVITY

Activity	Classifiers			
	Default classifier not scaled	Default classifier scaled	Person classifier	Default classifier after learning
Standing	95.5%	98.1%	99.8%	98.4%
Sitting	35.9%	41.7%	100%	97.3%
Lying	81.6%	75.3%	98.3%	93.3%
Sitting on the ground	28.8%	52.0%	0%	84.5%
On all fours	100%	98.0%	0%	71.7%
Going down	52.0%	54.7%	0%	45.3%
Standing up	56.7%	58.6%	0%	74.5%
Falling	3.6%	9.1%	0%	11.0%
<b>Classifier accuracy</b>	<b>73.0%</b>	<b>79.0%</b>	<b>69.0%</b>	<b>84.5%</b>

## V. EXPERIMENTAL RESULTS

This section describes the experiment of the classifier adaptation procedure consisting of the initialization procedure and active semi-supervised learning. The Default classifier used for the experiment has accuracy of 73% when the current user is tested. Such low accuracy is achieved since the current user is shorter than the users whose data was used to build the Default classifier. More precisely, low accuracy is achieved during the classification of the basic activities, namely sitting (35.9% accuracy) and lying (81.64% accuracy). The low accuracy of sitting is caused by mistakenly classifying sitting as sitting on the ground. The accuracy of the classification for each activity can be seen in Table 3.

The first step of the adaptation consists of scaling the Default classifier to the current user height. This was done by scaling the attributes related to the user height using the equation (1), where the height was reduced from 176 cm to 160 cm. The scaling increased the accuracy of the Default classifier by six percents thus the final accuracy was 79%. By scaling previously described attributes we have

increased the accuracy of the classification of almost all activities except lying and on all fours, where the accuracy has decreased. The reason is that the height

of the person does not affect certain activities like falling.

	falling	lying	sitting	standing	on all fours	sitting on the ground	going down	standing up
falling	6	8	0	14	14	0	5	12
lying	0	557	0	0	40	0	0	0
sitting	2	0	328	0	0	0	5	2
standing	0	0	0	1279	0	0	6	15
on all fours	2	4	7	0	81	13	0	6
sitting on the ground	0	19	0	0	1	168	0	11
going down	8	25	2	9	2	0	38	0
standing up	2	6	5	11	10	1	0	102

Figure 4. Confusion matrix of the Default classifier after the active semi-supervised learning was applied.

The Person classifier used in this experiment is described in Section IV.A.2. We have used 30 seconds of each basic activity to build the classifier. Its accuracy is 69%. The accuracy of classification of the basic activities is seen in Table 3. This classifier and the scaled Default classifier were used by the active semi-supervised learning process. The test of this process was done by using three 60 minutes recordings of unlabeled data of the current user. Those data were balanced to the percentages of the average activities in daily living that are shown in Fig. 5. Each recording was used twice. During the active semi-supervised learning, each instance with 100% confidence was added to the learning set of the Default classifier four times. This classifier was rebuilt every five minutes. The result was increased accuracy of the Default classifier from 79% to 84-85%.

Accuracy of the individual activities has increased (e.g., sitting from 35.9% to 97.3%) except those activities that could be easily misclassified as lying. Even the recognition of the falling activity has increased even though it is the shortest activity to classify. The confusion matrix of the final classifier with accuracy 84.5% (Fig. 4) reveals the misclassification problem. The error is a result of scaling the attributes in lying instances. Exclusion

of these instances from scaling should be done in further research.

## VI. CONCLUSION

This paper describes the adaptation part of the Confidence system. The main module of Confidence is the activity recognition module that uses three classifiers to recognize current activity of the user, and all three classifiers are adjusted to each particular user. The initialization procedure includes the scaling of the activity recognition classifiers and their update using active semi-supervised learning. With the usage of the initialization procedure, the accuracy of the activity recognition module in the experiments increased from 73% to 84%. To achieve this improvement, several reasonably novel approaches were designed. Overall, the Confidence system is now in the extensive testing phase by several users and independent reviewers. The results so far, including a live demonstration at the ICT Digitally Driven 2010 Event in Brussels were better than promised in the project proposal.

In the future work, certain activities will be excluded from the scaling process, new attributes will be added to the activity recognition classifiers, e.g., the ratio of different activities in the data, history of the classification for Default and Person

classifier, and more complex statistics. Besides, the aging of the data will be added to the learning data by removing the oldest data from the classifiers. Future work also includes extensive testing of the method with various end users.

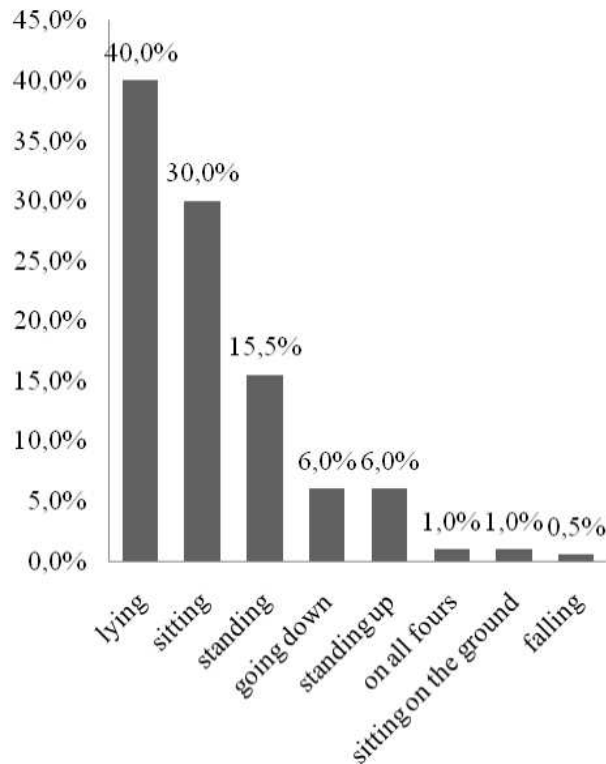


Figure 5. Percentage of activities during the day.

#### ACKNOWLEDGMENTS

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# Improving a Localization System for Ambient Assisted Living

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**Abstract**—This work presents a new positioning estimator for indoor localization systems that can be employed in ambient assisted living applications. This novel positioning algorithm is able to improve the accuracy of the tag position estimation and does not require increasing the number of fixed sensors of the localization system. This way, the intrusiveness and the cost of the proposed system is reduced.

## I. INTRODUCTION

During the last decades, Information and Communication Technologies (ICTs) have become an essential part of people life improving the health situation of European population. The use of ICTs in Ambient Assisted Living (AAL) provides elderly people with a sense of security which allows them to live independently, to maintain an active participation in society and to improve their quality of life.

The CONFIDENCE project [1] has developed a care system that has the potential to detect abnormal events, such as falls, or unexpected behaviors that may be related to health problems. To detect these situations, the users location is analyzed using a Wireless Sensor Network (WSN). This localization system provides the reconstruction and interpretation subsystem with information on the absolute positions of the mobile sensors or tags placed on the human body for gesture representation and further event or motion behavior analysis. WSN is the appropriate solution to implement the localization system thanks to its lower consumption, cost and versatility.

A traditional positioning system consists of a group of fixed sensors, whose position is known,

and one or more tags to be located [2]-[4]. The fixed sensors are able to estimate the distances to the tags. The localization procedure involves two steps. Firstly, the distances between each fixed sensor and the tag are estimated using ranging algorithms. In a second step, the position of each tag is estimated with a positioning algorithm using these estimated distances. Only four fixed sensors are necessary to obtain the  $(x, y, z)$  coordinates of the tags, but due to reflections in the traveling signals and errors in the communications between sensors, a bigger number of fixed sensors is usually set to improve the accuracy of the positioning estimations. The increment in the number of sensors implies a higher cost of the system and results in a more intrusive solution.

This paper presents a new positioning method based on the Recursive Least Square (RLS) algorithm [5] that improves the accuracy of the traditional positioning algorithms. The proposed positioning algorithm does not require an increased in the number of fixed sensors to present good positioning accuracy. Thus, the cost and intrusiveness of the localization system will be reduced.

The rest of the paper is organized as follows. Section II presents the system model usually used in the positioning systems, resumes the most known positioning algorithms and presents the proposal of this work. Section III shows the simulation results obtained in the four 3D positioning systems. Lastly, Section IV portrays the conclusions of this paper.

## II. POSITIONING ALGORITHMS

### A. System model

A classical positioning system for indoor environments is defined by  $N$  fixed sensors and  $M$  mobile sensors or tags, with  $M \geq 1$ . These positioning systems are able to estimate with a certain ranging algorithm the distances  $\{d_{i,j}\}$  among the  $i^{\text{th}}$  tags and the  $j^{\text{th}}$  fixed sensors, with  $i = 1, \dots, M$  and  $j = 1, \dots, N$ .

Using the information of the distances  $\{d_{i,j}\}$ , the positioning algorithms estimate the position of the  $i^{\text{th}}$  tag,  $\boldsymbol{\theta}_i = (x_i \ y_i \ z_i)^T$ , where  $(\cdot)^T$  represents the matrix transpose. To that end, the next equation has to be solved:

$$\mathbf{A} \cdot \boldsymbol{\theta}_i = \mathbf{b}_i \quad (1)$$

where the  $n^{\text{th}}$  row of the matrix  $\mathbf{A}$ , with  $n = 1, \dots, N-1$ , will be

$$\mathbf{a}_n = 2 \cdot (X_{n+1} - X_1 \quad Y_{n+1} - Y_1 \quad Z_{n+1} - Z_1), \quad (2)$$

and the  $n^{\text{th}}$  row of the vector  $\mathbf{b}_i$ , with  $n = 1, \dots, N-1$ , will be

$$b_{i,n} = d_{i,n+1}^2 - d_{i,1}^2 + k_1 - k_{n+1} \quad (3)$$

$(X_{n+1}, Y_{n+1}, Z_{n+1})$  in (2) are the coordinates of the fixed sensor  $n+1$ . In (3),  $d_{i,n+1}$  is the estimated distance between the  $i^{\text{th}}$  tag and the  $(n+1)^{\text{th}}$  fixed sensor and  $k_{n+1} = X_{n+1}^2 + Y_{n+1}^2 + Z_{n+1}^2$ .

There are different approaches to obtain the desired vector  $\boldsymbol{\theta}$ . In the following sections, the Least Square (LS) and the Recursive Least Square (RLS) algorithms are introduced.

### B. Least Square Method (LS)

In the LS method, the equations system presented in (1) is directly solved, so that [6]:

$$\hat{\boldsymbol{\theta}}_i = (\mathbf{A}^T \cdot \mathbf{A})^{-1} \cdot \mathbf{A}^T \cdot \mathbf{b}_i, \quad (4)$$

where  $(\cdot)^{-1}$  represents the matrix inverse.

### C. Recursive Least Square Method I (RLS)

In order to avoid the matrix inversion of the LS method in (4), the RLS algorithm [5], solves iteratively the  $(N-1)$  equations system in (1) in the following way:

$$\hat{\boldsymbol{\theta}}_{ik} = \hat{\boldsymbol{\theta}}_{i(k-1)} + \mathbf{m}_{ik} \cdot (\mathbf{b}_{i,n} - \mathbf{a}_n \cdot \hat{\boldsymbol{\theta}}_{i(k-1)}) \quad (5)$$

where,  $\hat{\boldsymbol{\theta}}_{ik}$  is the estimation of  $\boldsymbol{\theta}_i$  in the  $k^{\text{th}}$  iteration.

$$\hat{\boldsymbol{\theta}}_{ik} = (\hat{x}_{ik} \quad \hat{y}_{ik} \quad \hat{z}_{ik})^T, \quad (6)$$

and

$$\mathbf{m}_{ik} = \frac{\mathbf{P}_{i(k-1)} \cdot \mathbf{a}_n^T}{\mathbf{a}_n \cdot \mathbf{P}_{i(k-1)} \cdot \mathbf{a}_n^T + 1}, \quad (7)$$

$$\mathbf{P}_{ik} = (\mathbf{I} - \mathbf{m}_{ik} \cdot \mathbf{a}_n) \cdot \mathbf{P}_{i(k-1)}, \quad (8)$$

being  $\mathbf{I}$  a  $(N-1)$  dimension identity matrix.

With an initial guess of  $\boldsymbol{\theta}_{i0}$ , (5) is sequentially solved using the  $(N-1)$  rows of matrix  $\mathbf{A}$  and vector  $\mathbf{b}$ . This process is iterated  $R$  times. Thus, the total number of iterations is  $(N-1)R$ .

### D. Recursive Least Square Method II (RLS)

In this work, we propose a new approach to the RLS algorithm [5], to solve the  $(N-1)$  equations system in (1). The solution will be:

$$\hat{\boldsymbol{\theta}}_i = \hat{\boldsymbol{\theta}}_{i-1} + \mathbf{m}_i \cdot (\mathbf{b}_{i,n} - \mathbf{a}_n \cdot \hat{\boldsymbol{\theta}}_{i-1}) \quad (9)$$

where,  $\hat{\boldsymbol{\theta}}_i$  is the estimation of the coordinates of the tag in the time instant  $t^{\text{th}}$ .

$$\hat{\boldsymbol{\theta}}_i = (\hat{x}_i \quad \hat{y}_i \quad \hat{z}_i)^T \quad (10)$$

and

$$\mathbf{m}_i = \frac{\mathbf{P}_{i-1} \cdot \mathbf{a}_n^T}{\mathbf{a}_n \cdot \mathbf{P}_{i-1} \cdot \mathbf{a}_n^T + 1}, \quad (11)$$

$$\mathbf{P}_i = (\mathbf{I} - \mathbf{m}_{i-1} \cdot \mathbf{a}_n) \cdot \mathbf{P}_{i-1}. \quad (12)$$

With an initial guess of  $\boldsymbol{\theta}_0 = [0 \ 0 \ 0]$  and an initial value of  $\mathbf{P}_0 = \mathbf{I}$ , (9) is sequentially solved using the  $(N-1)$  rows of matrix  $\mathbf{A}$  and vector  $\mathbf{b}$ . For the next position estimation,  $\boldsymbol{\theta}_i$  and  $\mathbf{P}_i$  are stored and used as initial guess. Thus, to estimate the  $\boldsymbol{\theta}_i$  the  $(N-1)$  equations system in (9) are solved iteratively using  $\boldsymbol{\theta}_{i-1}$  and  $\mathbf{P}_{i-1}$ . Additionally, every  $l$  new received measurements, the matrix  $\mathbf{P}_i$  will be reset to the identity matrix.

## III. SIMULATION RESULTS

Four localization systems with different number of fixed sensors and tags have been considered in this section. The first



TABLE I.  
ERROR IN THE ESTIMATION OF THE POSITION FOR THE SAME  
NUMBER OF ELEMENTS AND A ROOM  $9 \times 9 \times 3 \text{ m}^3$  WITH THE  
RLS I,  
 $\mu_d = 0.05 \text{ m}$  AND  $\sigma_d = 0.2 \text{ m}$

Tag	$N = 8 \ M = 1$		$N = 4 \ M = 5$	
	$\mu_p \text{ (m)}$	$\sigma_p \text{ (m)}$	$\mu_p \text{ (m)}$	$\sigma_p \text{ (m)}$
i = 1	0.39	0.05	0.48	0.08
i = 2	-	-	0.48	0.08
i = 3	-	-	0.49	0.08
i = 4	-	-	0.48	0.08
i = 5	-	-	0.47	0.08

TABLE II.  
ERROR IN THE ESTIMATION OF THE POSITION FOR THE SAME  
NUMBER OF ELEMENTS AND A ROOM  $9 \times 9 \times 3 \text{ m}^3$  WITH THE  
RLS II,  
 $\mu_d = 0.05 \text{ m}$  AND  $\sigma_d = 0.2 \text{ m}$

Tag	$N = 8 \ M = 1$		$N = 4 \ M = 5$	
	$\mu_p \text{ (m)}$	$\sigma_p \text{ (m)}$	$\mu_p \text{ (m)}$	$\sigma_p \text{ (m)}$
i = 1	0.26	0.02	0.29	0.02
i = 2	-	-	0.29	0.02
i = 3	-	-	0.29	0.03
i = 4	-	-	0.29	0.03
i = 5	-	-	0.28	0.02

one has  $N = 8$  fixed sensors and  $M = 1$  tag, whose position is desired to know. The second localization system has  $N = 8$  fixed sensors and  $M = 4$  tags. The third one has  $N = 4$  fixed sensors and  $M = 5$  tags and the last one has  $N = 4$  fixed sensors and  $M = 4$  tags.  $10^5$  different configurations have been simulated in each system, where the tags moved randomly around the room with a maximum speed of the tags of  $v_{\max} = 5.56 \text{ m/s}$ . New ranging estimations are received every  $\Delta = 24 \text{ ms}$ . Every  $l = 15$  measurements the matrix  $\mathbf{P}$  was reset in the RLS II.

A room of size  $9 \times 9 \times 3 \text{ m}^3$  has been considered. For the first and second systems, the eight fixed sensors have been located in each of the corners of the room; for the third and the fourth systems, two of the four sensors have been placed in one diagonal at  $0 \text{ m}$  height and the other two have been placed in the other diagonal at  $3 \text{ m}$  height. The error of the distance estimation among sensors is assumed to be normally distributed  $N(\mu_d, \sigma_d^2)$ .

Table I shows the mean and the standard deviation the position estimation error of each tag for a system with  $N = 8$  fixed sensors and  $M = 1$  tag and for a system with  $N = 4$  fixed sensors and  $M = 5$  tags when the RLS I algorithm is used. Note that

both systems require the same number of electronic devices (i.e.: nine). An error in the ranging estimation of mean  $\mu_d = 0.05 \text{ m}$  and a standard deviation  $\sigma_d = 0.2 \text{ m}$  has been considered. On the other hand, Table II shows the mean  $\mu_p$  and the standard deviation  $\sigma_p$  of the position estimation error of each tag when the RLS II algorithm is used in the same systems and configurations. Table I shows that the RLS I algorithm has a mean error in the tags localization of  $\mu_p = 0.39 \text{ m}$  when  $N = 8$  fixed sensors are used and  $\mu_p = 0.48 \text{ m}$  when only  $N = 4$  fixed

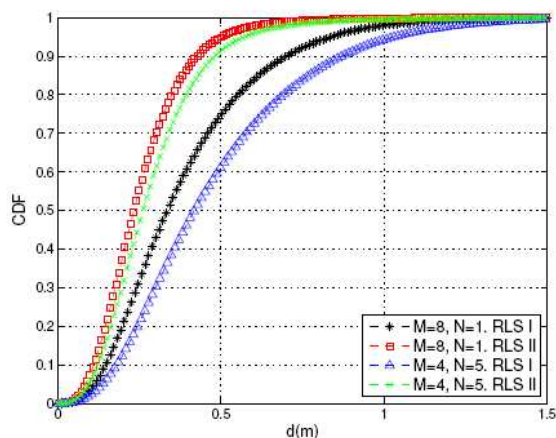


Figure 1. CDF of the positioning estimation of tag  $i = 1$ , with  $\mu_d = 0.05 \text{ m}$ ,  $\sigma_d = 0.2 \text{ m}$ .

sensors are used. It can be observed that, for the RLS I algorithm, an increase in the number of fixed sensors implies an improvement of around 20% in the accuracy of the position estimation. On the other hand, Table II shows that the RLS II algorithm has a mean error in the tags localization of  $\mu_p = 0.26 \text{ m}$  when  $N = 8$  fixed sensors are used and  $\mu_p = 0.29 \text{ m}$  when only  $N = 4$  fixed sensors are used. If we compare the results presented in Table I and Table II, we can observe that the RLS II algorithm presents an improvement in the accuracy in the positioning estimator of more than 60%. Moreover, for the RLS II algorithm, the system with four fixed sensor achieves nearly the same mean error as the system with eight fixed sensors.

Figure 1 presents the Cumulative Distribution Function (CDF) for the tag  $i = 1$  for the selected room of size  $9 \times 9 \times 3 \text{ m}^3$  and under the same simulation conditions as in Table I and in Table II. The CDF provides the probability of the distance error in the estimated position to be below a certain distance  $d$ . It can be observed that the system with

$N = 8$  fixed sensors has an error in the position estimation of the tags smaller than 0.84 m in the 95% of the cases when the RLS I algorithm is used and smaller than 0.50 m when the RLS II algorithm is employed. When only  $N = 4$  fixed sensors are used, the error is smaller than 1.03 m in the 95% of the cases when the RLS I algorithm is used and smaller than 0.57 m when the RLS II algorithm is employed. Hence, we can conclude that, the proposed RLS II algorithm presents better accuracy than the RLS I algorithm. Additionally, for the RLS II algorithm, an increase in the number of fixed sensors does not imply a significant improvement in the accuracy of the system.

Table III and Table IV present, for two different localization systems, the accuracy of the RLS I algorithm and of the RLS II algorithm respectively. In the first system,  $N = 8$  fixed sensors and  $M = 4$  tags are used; in the second system,  $N = 4$  fixed sensors and  $M = 4$  tags are employed. We can observe that in both systems four tags are used, as required by the CONFIDENCE system; the only difference is in the number of fixed sensors. For both systems, an error in the ranging estimation of mean  $\mu_d = 0.05$  m and a standard deviation  $\sigma_d = 0.2$  m has been considered to obtain the

TABLE III.  
ERROR IN THE ESTIMATION OF THE POSITION FOR TWO SYSTEMS WITH EQUAL NUMBER OF TAGS IN A ROOM  $9 \times 9 \times 3$  m<sup>3</sup> WITH THE RLS I,  $\mu_d = 0.05$  m AND  $\sigma_d = 0.2$  m

Tag	$N = 8$ $M = 1$		$N = 4$ $M = 5$	
	$\mu_p$ (m)	$\sigma_p$ (m)	$\mu_p$ (m)	$\sigma_p$ (m)
i = 1	0.26	0.02	0.29	0.02
i = 2	-	-	0.29	0.02
i = 3	-	-	0.29	0.03
i = 4	-	-	0.29	0.03

TABLE IV.  
ERROR IN THE ESTIMATION OF THE POSITION FOR TWO SYSTEMS WITH EQUAL NUMBER OF TAGS IN A ROOM  $9 \times 9 \times 3$  m<sup>3</sup> WITH THE RLS II,  $\mu_d = 0.05$  m AND  $\sigma_d = 0.2$  m

Tag	$N = 8$ $M = 4$		$N = 4$ $M = 4$	
	$\mu_p$ (m)	$\sigma_p$ (m)	$\mu_p$ (m)	$\sigma_p$ (m)
i = 1	0.39	0.05	0.48	0.08
i = 2	0.39	0.05	0.48	0.08
i = 3	0.38	0.05	0.49	0.08
i = 4	0.35	0.04	0.49	0.08

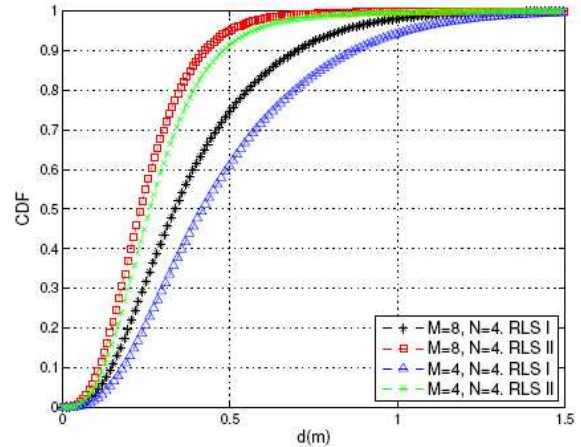


Figure 2. CDF of the positioning estimation of tag  $i = 1$ , with  $\mu_d = 0.05$  m,  $\sigma_d = 0.2$  m.

simulation results shown in Table III and Table IV. Both tables show the mean  $\mu_p$  and the standard deviation  $\sigma_p$  of the position estimation error for each tag. It can be observed in Table I that the RLS I algorithm has a mean error in the tags position of  $\mu_p = 0.38$  m when  $N = 8$  fixed sensors are used and of  $\mu_p = 0.48$  m when  $N = 4$  fixed sensors are employed. On the other hand, when the RLS II algorithm is employed in a system with  $N = 8$  fixed sensors, a mean error in the tags position of  $\mu_p = 0.25$  m is obtained. When only  $N = 4$  fixed sensors and the RLS II algorithm are used, this mean error remains around  $\mu_p = 0.29$  m.

Figure 2 presents the Cumulative Distribution Function (CDF) for the tag  $i = 1$  for the selected room and under the same simulation conditions as in Table III and Table IV. Figure 2 shows that for the room of size  $9 \times 9 \times 3$  m<sup>3</sup>, the system with  $N = 8$  fixed sensors has an error in the position estimation of the tag smaller than 0.83 m in the 95% of the cases when the RLS I algorithm is employed and smaller than 0.50 m with the RLS II algorithm is used. For the system with  $N = 4$  fixed sensors and  $M = 4$  tags, the positioning error is smaller than 1.03 m if the RLS I algorithm is implemented. If the proposed RLS II algorithm is employed, the positioning error of the system is smaller than 0.57 m in the 95% of the cases. We can observe that, when the RLS I algorithm is used, the increase in the number of fixed sensors leads to an increase in the accuracy of the position estimation. However, when the RLS II algorithm is employed, increasing the hardware requirements of the system may not



be so interesting, as the accuracy of the system will not improve significantly.

#### IV. CONCLUSION

This paper presents an improved RLS algorithm for indoor localization systems. A comparison between the traditional RLS algorithm, the RLS I algorithm, and the new one, the RLS II algorithm, has shown the benefits of this new approach.

Four different systems have been studied. In all cases, the new approach of the RLS algorithm obtains better estimations of the position of the tags. Additionally, the simulation results have shown that an increment in the number of fixed sensors with any number of tags, does not always lead to a significant improvement in the accuracy of the position estimation of the tags. In fact, when the RLS II algorithm is employed, the small improvement in accuracy may not be worth increasing the number of fixed sensors.

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## Poster abstracts



# Personal Mobile Space

Using mobile applications to support the work-related well-being of 50+ employees

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## *Introduction*

Personal Mobile Space (*Arjen mobiilipalvelut*) is an ongoing research project aiming to find solutions for supporting and promoting well-being and learning with mobile technology. The project addresses a vast range of different audiences, and one part of the research focuses on the aging population. When defining the exact goals for the project, one of the general concerns that were raised was the need to support the transition from working life to retirement by providing aging employees with tools which would enable and motivate them to actively monitor and enhance their well-being. Therefore, developing concepts of mobile solutions which address this need became the goal of one case project of the Personal Mobile Space project. In this poster, we present the background of this particular case project, the outcomes of its initial phases, and the future steps to be taken.

## *Methods*

We employ a user-driven approach consisting, firstly, of workshops for defining the goals and needs and, secondly, field trials for evaluating the concepts and acquiring the users' experiences. In this case, the well-being of aging employees was set as a general project aim in a stakeholder workshop with representatives of a municipality. A user workshop was then organized with eighteen over 50-year-old office employees from this municipality in order to get an understanding of problems in their working environment and ideas for improving their well-being. In the workshop, ideas and goals for possible mobile concepts were discussed. The participants also answered three open-ended questions in written form, addressing current problematic issues about their work and their ideas for activities or mobile solutions that would support their work-related well-being.

## *Results*

The most problematic issue, according to the employees, was rush (mentioned by 14 out of the 18 participants). Other frequently mentioned issues included physical pain (9/18), demanding tasks (7/18), problems with other employees (7/18) and working posture (6/18). Other problems included lack of physical activity, mental stress, schedules, changes in work tasks, sleeping problems, and some problems with aging. When asked about activities that would improve work-related well-being, more than half of the participants (10/18) brought up exercise breaks during the day. Several of them also mentioned exercise guidance in general, nutritional guidance, and improving the community spirit. Similar issues were highlighted also when the participants were asked how mobile applications might be able to support their well-being. Mobile exercise instructions and related reminder alerts were mentioned by several participants, as well as ways of monitoring and enhancing motivation for free-time physical activity.

## *Discussion*

Based on the outcomes, we are currently exploring mobile solutions for aging employees to improve their well-being both in and outside of the work place. We try out different mobile-based concepts with them, looking for solutions which encourage them to independent physical activity, better quality of everyday life and well-being after their career. Two main concepts are being developed.

The first one is related to exercise breaks in the work place, based on an exercise program via mobile phone. Employees can work out with the aid of video-based instructions, send feedback and get reminders with help of a mobile phone. An eight-week field trial period of the exercise program will be carried out this autumn with 11 office employees. Everyone is recommended to work out twice a day, 5 minutes at a time. Besides acquiring views on the user experience and the usability of the solution, we also examine different aspects related to health (e.g. body mass index, body fat percent, and waist circuit to evaluate the impacts of exercise) as well as mental and physical stress.

The other main concept is related to independent free-time physical activity. It will be based on the idea of mobile routes outdoors, with checkpoints which, firstly, provide an easy way to record one's activity and, secondly, may contain interactive elements. The routes will be planned collaboratively with the aforementioned user group, and field trial periods will be organized.

*Keywords:* mobile technology, well-being, ageing population, office work, exercise break, physical activity, motivation

# Impacts and Accessibility of Sticks:

Innovative devices for health promotion and memory support

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## *Introduction*

This research focuses on two innovative devices that are being developed for enhancing well-being of senior citizens. ThehStick – health stick – is a modernised version of the so-called SOS Passport, in which various health-related data may be saved (blood group, illnesses, vaccinations, medication, care will, etc.). It functions as a safety device in case of acute illnesses or injuries and a means for self-care and promotion of one's own health. The mStick is a memory and reminiscence stick; a biographical memory store, and a device supporting memory and testing it. Personal biographical documents and materials related to the stick owner's interests are saved in it. Its memory test and game applications serve those with memory problems, but it also serves active old people by providing meaningful entertainment. It is an excellent assistive device for care workers. The philosophy behind the hStick is that a human being is interested in her/his own well-being. The stick stimulates people to monitor and promote their own health. It makes contacts with social and health care transparent. It may be useful when testing medication and learning self-care (e.g., diabetes), or when mapping insomnia or feelings of pain. The philosophy behind the mStick is based on the notion that a human being is a biographical creature, whose memory never disappears completely – let alone memories. It enables bed-ridden people's connections to other places and other times; improves quality of life of residents in institutional care and also enriches social life of healthy old people, and promotes and cultivates communication and inter-generational interaction. Ordinary USB sticks (and similar gadgets) function as devices for information storage. Sticks are in the forefront of the developments in gerontechnology. They represent avantgarde but user-driven technology that empowers rather than labels; they imply proactive and tailor-made rather than reactive and standardized solutions; and the focus is on quality of life rather than on health alone. The concrete starting point – the stick itself – is simple, but the concept is linked to a wide range of research and development activities.

## *Methods*

The sticks are being piloted among groups of elderly people in the Lahti region in Finland. A larger number of pilots in different environments are to be launched in late 2010– early 2011. The early piloting phase has been studied by means of interviews. The pilots to be launched will be studied in a systematic manner throughout their implementation. The research approaches to be utilized are (i) assessment of impacts of sticks on the elderly users, their near relatives, care personnel, care organizations, and the society, and (ii) research of accessibility and usability of the sticks. Impacts are understood in a wide sense covering, for instance, social, health, cultural and economic impacts. Methodologies developed for Human Impact Assessment studies will be utilized [1]. Research of accessibility and usability will be based, for instance, on international standards concerning human–system interaction. In addition to interviews, research methods include observation, use of learning diaries and surveys.

## *Results to be expected and conclusion*

The research is at its early stages as part of a R&D project that started in August 2010. Some early results will be available by the end of 2010. The large R&D project that lasts until the end of 2013 provides an excellent opportunity for long-term impact and accessibility assessment. The project is implemented by

University of Helsinki, Palmenia Centre for Continuing Education in collaboration with Lappeenranta University of Technology, Lahti School of Innovation. It is funded by the Regional Council of Päijät-Häme. Experts in several scientific disciplines (such as social gerontology, nutrition, health sciences, gerontechnology, design, art-based methods, user-driven innovations and business management) are involved. Results of the research are expected to shed light on users' needs; good practices in user-driven, practice-based technology and service development; technical accessibility and usability; social, economic and other types of impacts on different stakeholders involved, and promotion of innovation processes. As a developmental outcome of the project, an operational model for content production and exploitation of the sticks will be drafted. The research responds to challenges in service production brought about by the ageing of the population. Results will be of use for public, private and non-governmental third sector organizations, educational organizations, private citizens, their near relatives, and individual care workers. The project provides a multi-faceted basis for research and development of service, content and product design to support elderly people's responsibility and activity in issues related to their well-being.

*Keywords:* gerontechnology, health promotion, memory support, impact assessment, accessibility, user-driven innovation

[1] Reference: Raappana, Anu; Rauma, Marika & Melkas, Helinä (2007) "Impact of safety alarm systems on care personnel", *Gerontechnology*, 6 (2), April, 112–117.



# Automatic Risk Detection for Enhancing Elderly's Mobility and Self-Efficacy

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## *Introduction*

In this paper we present an overview about a system developed within the Seventh Framework Program (FP7). The system is designed to detect a wide range of risks with a single sensor unit, enhancing mobility and enabling elderly to take active part in the self-serve society by reducing their fears. We utilize the flexibility of vision based sensors and combine it with acoustic event detection to enhance the reliability of the overall system. The potential dangers, which can be detected, include smoke/fire, flooding, falls or sudden changes in daily life caused by a deterioration of the health condition. The overall aim is the integration of the supply chain and the reduction of barriers (i.e. fears and concerns), which impedes the mobility of elderly people, often suffering from dementia or light loss of cognitive activities.

## *Methods*

We use cameras equipped with microphones as sensors, offering a flexible and extendable solution and being able to detect different kinds of events simultaneously by applying powerful computer vision and audio processing algorithms. Furthermore, a late fusion approach is used, performing analysis of the scene on each camera individually and combining the individual results to get an overall decision afterwards. To be able to visually detect risks, various pattern recognition and image processing algorithms are applied. The combination of motion detection and identification of feasible features results in a general form of risk detection, being able to cope with different risks.

## *Results*

Research has shown that elderly and their relatives usually have a lot of fears. These fears in general yield in a low self-efficacy causing less activity, as elderly are afraid of many things and thus trying to reduce the risk by avoiding them. Due to this attitude, muscle strength decreases leading to less participation in social life and reducing the quality of life tremendously. This often strengthens their fears from a psychological point of view but also from a physical point of view: due to reduced muscle strength the number of falls increases, yielding in a higher fear of falling. To enhance the participation of elderly in social life and their mobility, the prevalence of fears has to be minimized. Our system is able to provide safety, as in case of a fall or other danger (e.g. smoke due to cooking) an alarm will be activated automatically. Due to this feeling of safety, elderly in general have fewer fears as the consequences of any incident are reduced enormously. Hence there is no reason for avoiding activities any more, resulting in more active participation in the self-serve society which directly influences the wellbeing in general (higher muscle strength, less depressions,...). If elderly are feeling well, they have much more joy and thus being even more active.

## *Discussion*

The ethical and practical implications of this project are studied as well as possible side and long-term effects over the whole project duration, thus ensuring a focus on ethical and legal issues. Any kind of AAL-systems not only influences the primary end-users but the full range of persons linked to and related with them. AAL-systems have to be conceptualized as systems with an equilibrium of capabilities and degree of

intrusion: on the one hand, the more the system can detect and directly intervene, the higher the possibility of reducing cognitive demands for the end-user which can trigger negative side-effects: (a) changing the focus of control from internal to external, (b) reduced self-efficacy, (c) loss of responsibility. All of these factors are known to accelerate cognitive decline and foster depression. On the other hand, a system not perceived as present and reliable will miss its main purpose: to assist and to increase well-being and security.

### *Conclusions*

The straightforward integration of an ambient assisted technology in already existing buildings/houses/flats is essential to ensure a high user acceptance. Hence, small and flexible sensors are needed to provide a system with minimal intrusion. Visual and optical sensors are able to fulfill these needs and they are able to adapt to new scenarios easily. Employing this powerful system enhances elderly's self-efficacy as well as their mobility by reducing their fears.

*Keywords:* fears; sorrows; automatic risk detection; self-efficacy; barriers;