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Activity typologies as a design model for the ubiquitous detection of daily routines

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Abstract

Emerging technologies open up new visions and business potential for systems design and development in the areas of wellbeing and health. New technologies enable the detection of human performance and early changes in physical and cognitive functioning, making it possible to monitor an older person's wellbeing. This kind of technology or service sets significant requirements for design, as design concepts must be able to capture the complexity of people's daily lives in terms of activities and environments. Technology itself is "blind" unless designers can adapt it to human life. There is thus a distinct need for comprehensive design and development models that generate adequate human requirements for such design. Activity typologies described in this paper are an example of such life-based design relevant knowledge. They allow the detection of signals in daily routines that would predict a decline in the target person's functioning, and feed this data into design processes. They can be used to create a model for human requirements specification for such ubiquitous services that are grounded on the idea of detecting changes in human activity. The model presented in this paper is created in BeWell project and based on the theoretical frameworks of Life-Based Design and International Classification of Functioning, Disability and Health.

Keywords: aging, technology, home care, memory, activities of daily living

Introduction

Massively multifunctional technologies such as ubiquitous and autonomous technology are developing fast; innovations are directed towards all areas of life. Their development has opened new perspectives, and has huge business potential in the area of health technologies and gerontechnology [1]. Wireless network and sensor technologies, ranging from smart homes to environment monitoring, make it possible to monitor people's homes and activities and to detect human performance 24/7 [2,3]. Modern sensors are increasingly small and energy efficient, and thus suitable for long-term use. They can be used in various everyday contexts to detect subtle changes in daily performance that might indicate a particular problem. When paired with a sophisticated algorithm, sensors can be used to monitor a person's wellbeing and provide feedback to the users.

Increasingly affordable modern big data technologies create new potential for wellbeing monitoring. Technological enhancements in automated analysis and new software interfaces allow new ways to access and use the data. As the amount of information increases, the algorithms and software enable sophisticated combinations and real-time analysis of data.

Ubiquitous technology can actively involve people in understanding and acting on their wellbeing, thus empowering them to take control over their own lives. The ability to manage one's health allows people to benefit from new technology in many ways. Early recognition of various disabilities, chronic illnesses or memory disorder, for example, can pave the way for more accurate treatment and have a remarkable influence on people's lives, and even let them remain active and independent for longer.

A promising application in this field is the detection of decreasing functional and cognitive performance. Sensor technology, paired with adequate monitoring and assessment systems, can enable the monitoring of such parameters and recognize and report any critical changes. It is sensitive enough to detect symptoms and minor problems in cognitive functioning earlier than was previously possible. Instead of intervening only when the signs of cognitive decline are obvious, data generated by multiple sensors make it possible to detect minor changes in a person's daily activities [4,5].

Significant savings for society in terms of social and health care expenses

Possibility to objectively detect meaningful changes in functioning and performance over time, and to respond accordingly, is a substantial financial incentive to offer wellbeing services for the ageing population globally. A promising user group for these kinds of services is the global older consumer market: active seniors who seek products and services that advance their own wellbeing [6] and increase their quality of life [7]. Along with the growth in the number of senior citizens – 'the senior tsunami' – attention is increasingly paid to innovations that support active ageing in place [4, 8−9] and people's ability to remain at home [10]. This growth in silver markets [11−13] opens up new challenges as well as new requirements for the development of products and services. The critical question is how to adapt designs to suit these markets.

Given the potential of sensor technology, in particular its ability to help extend everyday coping in individuals' homes, it may also become an essential component of future integrated care information systems. Early efforts to bring technology to the home environment point to the usefulness of technology-supported services in keeping seniors out of institutional care. Kaye et al. (2011) [14] argue that home assessment provides the opportunity to assess activity in a person's typical environment, and is thus likely to represent a more relevant measure of real-world function. In addition to home-based activities, attention should also be paid to changes in social participation [15].

Aim of research

Modern sensor technology can provide data on numerous aspects of human performance. However, the interpretation of this data requires in-depth understanding of what the numerical sensory parameters indicate in terms of health and wellbeing of the target person. For example, what does gradual decrease in the speed of movements or in the amount of speech tell about? Thus, it makes sense to ask and to systematically study the meanings of changes in sensory-monitorable performance.

The research presented in this paper created a design model for planning the human dimension of such ubiquitous environments that are sensitive and responsive to the functioning and health of a person. The design model helps to analyse daily routines in order to notice early changes in cognitive or physical functioning.

The main research questions were:

1. How can daily life of older people be understood for design purposes?
2. How can this understanding be used to produce generic activity models?

3. Can activity models be used to define sense making parameters for sensor data analysis?

Theoretical background

As the ways in which technologies can be used to improve everyday human life are becoming increasingly sophisticated and complicated, understanding the human dimension of technology-supported services and applications has become a major design challenge. In the case of services that can detect a person's performance and activity, the preconditions for market success are not based on high technology, but rather on knowledge of the users and various contexts of everyday life [16,17].

Defining sense making parameters for analysing sensor data presupposes in-depth understanding of human functioning and daily life. We have applied Life-based design (LBD) approach to investigate the elements of everyday life [18]. This approach takes the analysis of human life as the basis of designing technology-supported services. LBD looks at the phenomena of human life from a multidisciplinary perspective: how people live and how technology can improve their quality of life. It starts by analysing what is needed to improve the quality of life, rather than how technologies should be used. The problem is thus structured around people's daily lived experiences and routines, and the design focus shifts from possible technological solutions to designing a good life: technology is seen in the context of supporting and advancing people's daily lives. By using well-grounded tools, and by exploiting the traditions of human research such as psychology and sociology, knowledge of everyday life is used to derive goals and human requirements for the design of technology-supported services.

LBD was used to create the model for the ubiquitous detection of human functioning and performance described in this article. The model is based on activity typologies, which describe a person's daily activities and performance to devise an appropriate long-term detection metric. The typologies are used as the basis for an augmented adaptive service that would measure the quality and quantity of action patterns, and analyse the data to compare situations and provide feedback.

Methodology

A form-of-life (FoL) analysis, a core element of LBD, was selected as a method to investigate people's daily routines as a starting point for developing the model. This information was supplemented by general knowledge of functioning and performance provided by the International Classification of Functioning, Disability and Health (ICF).

In the following, we will describe the nature of FoL analysis and the ICF, and then introduce the model of activity typologies as general descriptions of daily routines.

Form-of-Life (FoL) analysis

People's lives, to a great extent, are characterized by the different kinds of forms of life. FoL analysis focuses on identifying life situations, and then looks at people (and their activities and ways of being) to ascertain what comprises a good life. Only then is it possible to decide which service design alternatives will most improve the quality of life. FoL analysis is meant to produce initial ideas for the front-end design phase, and decisive information for further phases in the development process, such as concept development. It thus specifies the human requirements for the whole development process of technology-supported services.

FoL is a general concept used to define any system of actions in human life under examination and to help understand the contents of this particular area of life. It has been used as a part of sociological discourse, but should not only be studied from a sociological perspective. In addition to social elements, human FoLs are determined and shaped by many biological and psychological factors that together give meaning to people's actions and aims. An FoL includes predetermined factors in life as well as a complex variety of elements in everyday life. For example, being retired is an FoL, which affects people's social lives and is associated with their socio-cultural background. It is also related to ageing, which is both a social and biological phenomenon. Further, being retired involves many psychological aspects.

People participate in FoLs by sharing different rules and regularities that are typical of that particular FoL and by carrying out respective actions [18-19]. The concept 'form of life' originates from Wittgenstein's late philosophy. By this term, Wittgenstein, one of the most important philosophers of the last century, refers to any circle or context of linguistic actions. In his original proposal, form of life was a theoretical concept and conceptual abstraction for analysing human linguistic behavior and use of language. It is possible to extend the use of this concept to analyse, any other aspects of human life [18].

An FoL analysis starts by defining these rules and regularities [18]. Daily routines can be seen as regularities that people follow when they participate in a particular FoL. Therefore an FoL analysis can provide insights into a person's daily routines by separating the different contexts of life and examining their contents. It is thus a tool for exposing the relevant differences between different life settings, and for further understanding the regularities of a specific life situation. By defining and analysing an FoL, it is possible to understand what kinds of routines it contains. What do the target people do in their daily lives? How are their daily activities organised? How do daily routines differ between people? An FoL analysis provides valuable generic data about different groups of people, rather than individuals.

Daily routines – rule-following actions – are governed not just by humans' internal mechanisms (e.g., their cultural models and human agency), but also by the environment in which they live [20]. Thus, the key elements of studying daily routines are the agent, the goal of action, the context and the tool [21]. The agent is the person performing an activity, who perhaps uses a technology to support the action. The goal constitutes the effects of the action. It is dependent on the context of the action, which is a precondition of the performance to take place. The context can include social, psychological, technical, information and task-based elements. The tool can include a possible artefact or technology.

The mere discrimination of daily routines and regularities of an FoL does not provide sufficient information about people's actions. It is also essential to understand the internal structure of these actions and how they are integrated in order to define the relationships between them, extract their similarities and explicate the logic behind them [17,18]. The logic behind rule-following actions reveals why rules or routines make sense, what the goals of actions are and how the actions are integrated. In the search for logic, facts and values help explain why people perform particular actions [18,21] (Figure 1). Facts (such as age, gender, educational and work history, health and medical history) explain (and often even determine) the goals of rule-following actions and provide the limits – the possibilities and restrictions – on what people do in their lives. Values can explain the meaning behind the actions. They influence how people choose between different FoLs and between actions within them.

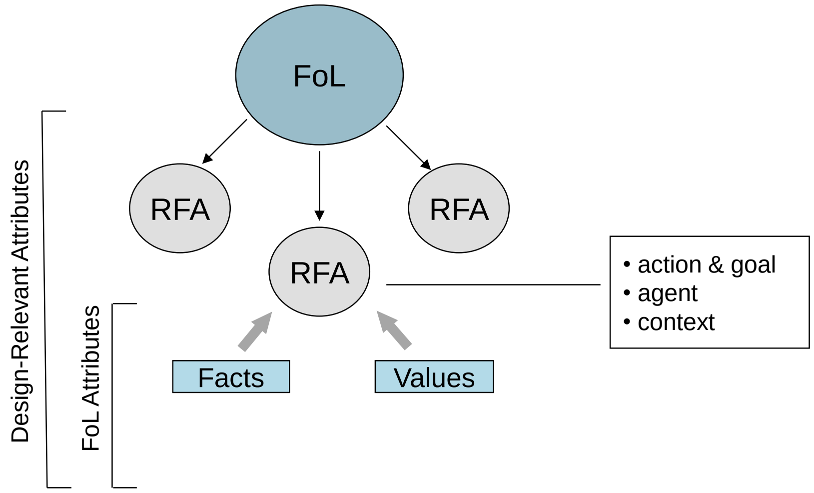

Figure 1. The function of rule-following actions, facts and values in analysing an FoL.
Note: FoL = form of life; RFA = rule-following action.

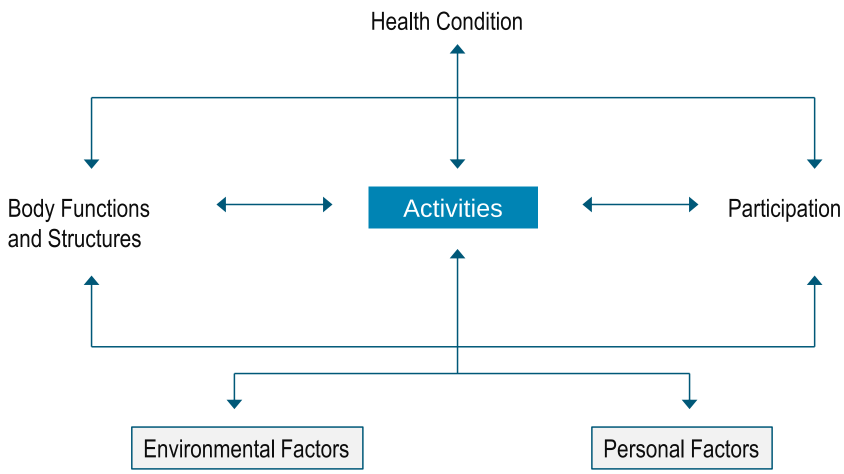

Figure 2. ICF components (adapted from WHO 2013).

Analysis of human functioning and performance

When the design aim is to create a system that detects early changes in older people's activity and behaviour, mere information about daily routines is not sufficient. When people age, they may start to experience age-related declines in physical or cognitive functioning. This change in abilities may also change their daily lives and routines. The challenge is to create a system that detects daily routines and perceives changes with detailed temporal precision in order to indicate the onset of cognitive or functional decline. Data about a person's functioning and performance are needed to support the description of daily routines.

Health care and rehabilitation professionals use the concept of functioning and performance to describe independent living and coping in everyday life. This concept reveals how the ability to manage everyday activities varies amongst people. Principles for this assessment can be found in the ICF model, which examines people's functioning and performance as a dynamic interaction between the individual, the activity and the environment. The World Health Organization

(WHO) introduced the ICF, which is an internationally accepted conceptual framework that describes the dynamic interactions between bodily functions, bodily structures, activities and participation, and environmental and personal factors [22] (Figure 2). The ICF model stresses the individuality of health and functional capability. It also offers a means of examining environmental factors in a structured manner, and thus serves as a welcome adjunct to FoL context analysis. It is helpful for identifying the principal problem of an individual's disability – the home environment, the limited capacity of the individual or a combination of these two factors. This helps identify the factors in the physical, social and attitude environment that support or inhibit participation in society and societal activities [22].

The ICF model focuses on impact [23]. This creates a foundation and a common framework with which to compare different conditions using a common metric – the impact on the functioning of the individual. This allows for the impact of the environment and other contextual factors on the functioning of an individual to be considered.

Results: A human-centric model for collecting sensor data

The aim of our research was to create a model for planning the human dimension of such ubiquitous environments that are sensitive and responsive to the functioning and health of a person. The design model would help to analyse daily routines in order to notice early changes in cognitive or physical functioning. In the following, we introduce the elements of the basic steps of the model created in the project.

Step 1: FoL analysis and ICF are used to describe daily routines

The first phase of the model is to use FoL analysis and ICF classification to describe the common course and content of the daily routines of a specific group of people (i.e., their patterns of sequences of actions). The actions can then be further divided into sub-actions and classified according to the ICF. These generic descriptions of the sub-actions classified using the ICF are called activity typologies.

Step 2: Activity typologies as general descriptions of daily routines

Activity typologies are used as a tool for planning and implementing services for the early detection of decreasing functioning and performance in older people. Generic activity typologies describe a person's daily performance, and can be used when tailoring an autonomous monitoring system to an individual. Using data gathered from self-assessment of the target individual and relevant stakeholders (such as home care givers, relatives and nearest ones) a generic activity typology can be fine-tuned into a sufficient illustration of a person's daily routines (Figure 3).

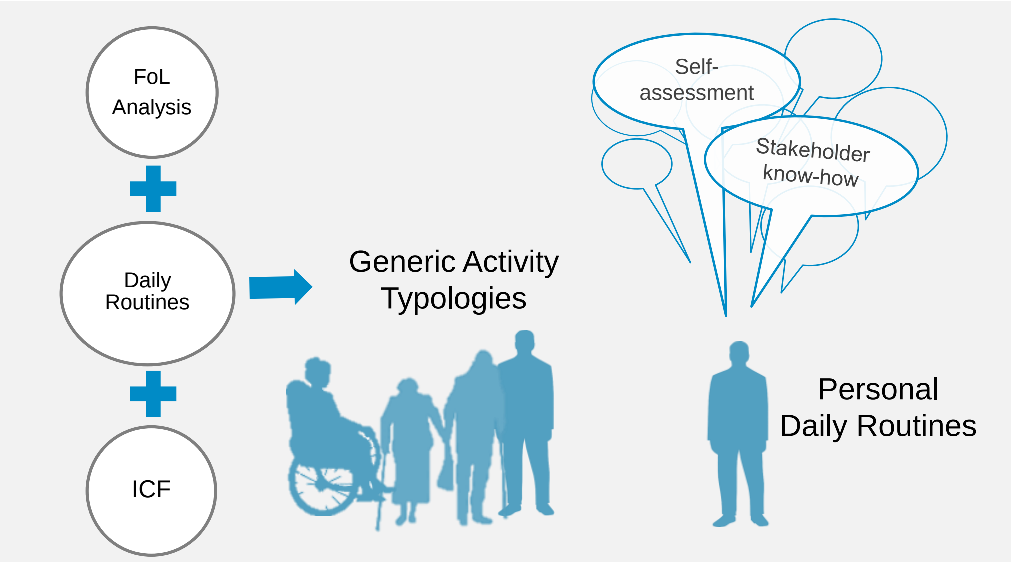

Figure 3. Generic activity typologies as a basis for illustrating personal daily routines.

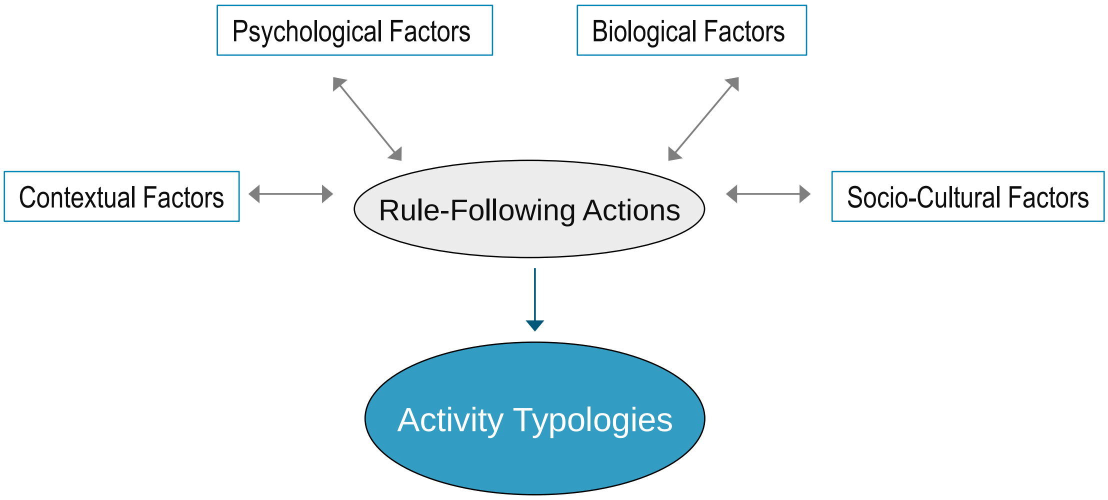

Figure 4. A design model for the ubiquitous detection of daily routines and activities.

Step 3: Analysis of meaningful actions

The next step from an application design point of view is to extract the actions that are meaningful in terms of monitoring changes in the person's functioning and performance. Specific actions in a typology can be used as indicators to determine what kind of human activity should be monitored, and what kind of performance parameters the technology should include. These parameters can then be used to create algorithms for monitoring. The human requirements based on FoL and ICF should answer questions such as how to determine which sequences of action are meaningful and which can be assessed with the help of technology. The sequences can be, for example, 'opening a door to the bathroom', 'getting dressed' or 'using a coffee maker in the morning'. A key question is what particular action (or chain of human actions) is powerful enough to signal a possible decline in the person's functional ability.

The ICF uses a combination of codes and qualifiers to describe functioning in a standardised manner ('no problem' to 'mild, moderate, severe and complete'), which is useful for developing an activity typology. Professionals, such as home health carers, should supply these assessments rather than interviewers [23].

Figure 4 illustrates the design model for the ubiquitous detection of human functioning and performance. The model provides a generic structure of how people perform their daily activities and routines. It also guides the technological solutions used to gather and further analyse the collected activity data.

Discussion

The design model illustrated in this paper has been discussed in several planning sessions with different stakeholders, and evaluated by health care professionals, and their feedback has been encouraging. However, the model is initial and naturally has to be elaborated and tested in real technology design processes.

What, then, would be the next development levels in order to turn the research into technology? The typologies give a clear idea of how sophisticated knowledge of human research in technology design can be compared to everyday and lay knowledge. A significant research challenge for future work is to further develop and test the generalizability of the tool, and to find methods of embedding the essential parameters of the analysis of everyday life efficiently into technology development processes. The important creative step in applying activity typologies to technology design is turning the explicit and implicit research embedded in them into technology and technical requirements. This step again presupposes a working discourse between human research paradigms and technology development.

By taking the aims and demands of the human dimension as the focal starting point for technology and service design, it is possible to create innovative value and a competitive edge in the silver markets. This paper discusses this ultimate design challenge: it introduces a model for planning the human dimension of ubiquitous environments that are sensitive and responsive to the functioning and health of a person. We have grounded the design on two theoretical approaches: LBD and ICF.

The usage of big data technologies [24] creates new insights into the prospects of monitoring the wellbeing of ageing people. Yet it also requires innovation in design practices. By introducing a model for the ubiquitous detection of human functioning and performance, we also sought to start a discussion about the necessity of well-grounded methods and tools for designing the human dimension of human-technology interaction design. Our paper illustrates how existing human research can be used to analyse human life and define technical design goals.

In this kind of innovation, involving all stakeholders – ranging from service providers to ageing people and their caregivers – is a prerequisite for a successful, responsible and ethically sustainable outcome [25-28]. Activity typologies have been developed based on the extensive and highly professional work of all such stakeholders. This novel, multidisciplinary way of approaching the service development process is built on a multi-actor ecosystem and goes beyond standard human-centred approaches. It includes a social co-design cycle that involves the simultaneous design of products, services and activities of people [29], in which co-creative 'learning by doing' is a key approach.

Conflict of interest statement

The authors of this article do not have any financial or personal relationship that could inappropriately bias their contribution.

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