Smart Objects: An Evaluation of the Present State Based on User Needs

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Abstract. In the last years, some attempts have been made to explore the use of smart objects, with the purpose of monitoring well-being and supporting people's independent living. However an inventory of characteristics of smart products currently available on the market is still lacking. The aim of this study is to provide an overview of such products in order to: (1) understand if their features really match users' needs, answering to the definition of assistive technology and, consequently, (2) understand if an environment embedded with SOs can be considered as assistive too, taking into consideration the attributes given by the definition of the SOs, of being embedded in familiar objects and immerse in the users' surround.

Keywords: Inclusive Design, Universal Design, Home Environment, Internet of Things.

1 Introduction

Nowadays, the most common definition of Smart Objects (SOs) describes them as everyday objects equipped with sensors, memory and communication capabilities [1, 2]. Consequently, SOs are able to capture information coming from the surrounding as well as to react on the basis of the user's needs [3]. The capability of interacting rapidly with the users represents their crucial feature, in addition to their intrinsic characteristic of being familiar tools for the users and, most of all, being "immerse" in the environment. Smart objects raise unique challenges and opportunities for designing interaction with intelligent systems, coping with the mostly limited interaction capabilities, exploring context information to provide more natural interaction, helping the user to understand the behavior and capabilities of the objects.

In a broader sense, SO are able to help people in participating in their environment through adaptation, accessibility and communication. Moreover, they can offer assistance

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N. Streitz and P. Markopoulos (Eds.): DAPI 2014, LNCS 8530, pp. 359–368, 2014.

to the elderly people's independent living. When applied to people with disabilities, a smart object can be considered an Assistive Technology (AT), in line with the definition given by Cowan and Turner-Smith [5]: "any device or system that allows an individual to perform a task that they would otherwise be unable to do, or increases the ease and safety with which the task can be performed".

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The aim of this study is to provide an overview of such products in order to:

- understand if their features really match users' needs, answering to the definition of assistive technology, and consequently
- understand if an environment embedded with SOs can be considered as assistive too, taking into consideration the attributes given by the definition of the SOs, of being embedded in familiar objects and immerse in the users' surround.

To this purpose, it was carried out a review of SOs currently available on the market. In particular the International Classification of Functioning, Disability and Health (ICF) [6] has been exploited in order to understand the ability of SOs to support people in the activities domains.

2 The Search Strategy

The first step of the research was the creation of an inventory of the smart assistive devices available on the market. For this purpose we conducted an Internet search, using the keyword "smart object". This preliminary step has highlighted a large improper use of the term "smart object", that becomes more a marketing term (e.g., any innovative product from a technical, esthetic and communicative point of view is called "smart"). For that reason, the detection of proper smart objects was complicated by the enormous quantity of retrieved tools. Consequently, several search strategies have been explored in order to select the most appropriate one, with the aim of guiding the search on the most appropriate SOs.

As a first step, we have compiled a list of household items (e.g., clothes, stairs, toilets, etc.) with which people come into contact every day. Also aids were included: in particular, we have considered the assistive device typologies collected by McCreadie and Tinker [7]. As a second step, keywords as "smart", "interactive" and "inclusive" have been selected, starting from the smart object definition. Objects and keywords have been then used together for the search, exploiting several combinations and search engines. Finally, both search engine tips and synonyms for the previous words have been considered.

For each object, it has been verified if it was compliant with the requirements and the producer company site has been investigated in order to find other products related to the search topics. At the end, the search strategy resulted in about 190 relevant smart devices. The objects can be classified in: Clothes (e.g., sweater, vest, etc.),

Clothing Accessories (e.g., shoes, elastic bands, bracelets, etc.), *Dishes* (e.g., forks, glasses, etc.), *Household Devices* (e.g. video-cameras, decorative objects, household appliances, etc.), *Medical Devices* (e.g., glucometer, sphygmomanometer, etc.), *Personal Care Products* (e.g., toothbrushes, toilet, etc.).

3 Smart Objects Evaluation Method Based on ICF

In order to systematically investigate how the available SOs are able to satisfy users' needs, it was decided to use the International Classification of Functioning, Disability and Health (ICF). The ICF has a universal application [8], as it allows describing the health and health-related states associated with all health conditions. It not focuses only on disable people but allow to describe the condition of any person. The domains contained in ICF are described from the perspective of the body, the individual and society in two basic lists: "Body Functions and Structures" and "Activities and Participation". The domains for the Activities and Participation cover the full range of life areas (from basic learning or watching to composite areas such as interpersonal interactions or employment).

In order to understand the extent to which SOs can be adopted to support a person in each activity domains, at first the parameter monitored and the information provided by the collected SOs have been analyzed. Then the relevance of this information respect to all the activity domains have been evaluated. The results of this first evaluation are reported in. The percentage has been calculated by considering the total amount of information related to each activity domain, in relation to the total amount of parameters provided by the collected SOs. As we can see, the majority of SOs is able to provide support with respect to three domains of activity: mobility (d4), self-care (d5) and domestic life (d6). It worth to underline that the sum of percentages differs from 100%. This is due to the fact that a parameter can support several activities domains.

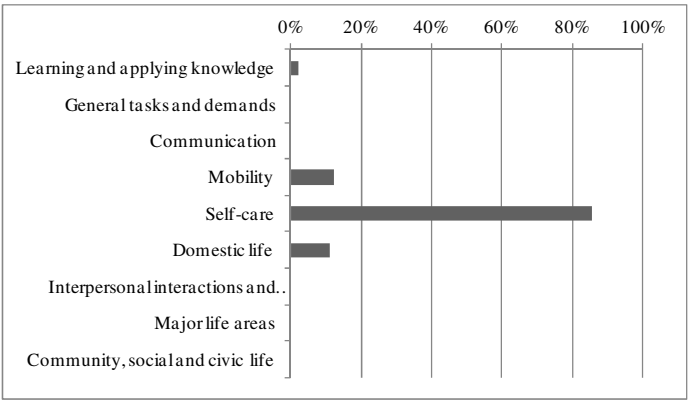

Fig. 1. Activities domain covering

As reported also in the most used tools in geriatric assessment, the Katz Index of Activities of Daily Living (ADL) [9], and the Instrumental Activities of Daily Living (IADL) [10], it is possible to assert that the ability to perform activity related to mobility, self-care and domestic life is a good predictor of elderly independence.

The shows that self-care is the most covered domain. Consequently a deeper investigation was conducted, in order to understand which activities, more related to this domain, are actually supported by SOs.

Through the analysis of the results, which are reported in, it is possible to observe that the majority of smart objects provides support to the activities related to "Looking after one's health" (d 570) and in particular they are focused on ensuring physical comfort, health and physical well-being by monitoring specific parameters, for the achievement of a better lifestyle ().

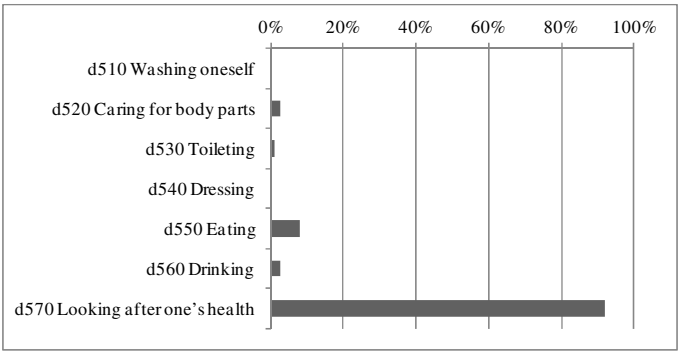

Fig. 2. Self-care domain covering

As far as the several functioning categories are concerned, these objects can help to maintain a balanced diet and an appropriate level of physical activity (d 5701) by monitoring eating habits and daily routines and by measuring physical parameters such as weight, body mass index and body water.

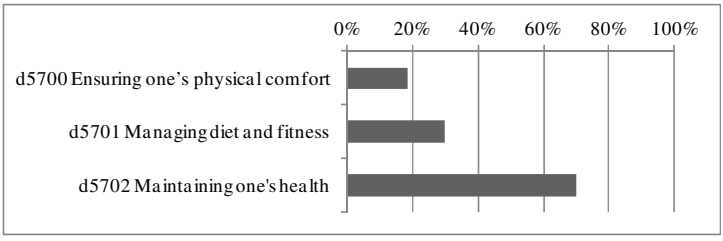

Fig. 3. Looking after one's health related activities covering

Maintaining one's health (d 5702) and looking after body parts are other important functions supported by intelligent devices. Indeed, they can support regular physical examinations, for example, by simply wearing smart clothes and/or accessories and/or

using smart toilets. In this way, appropriate algorithms analyze the parameters and generate alerts only when necessary, in order to prevent risks and reduce the need of professional assistance.

Other products aim at ensuring the user physical comfort (d 5700), supporting the domestic environmental care and informing the users about the current temperature or lighting, for example, and suggesting the most appropriate ones.

As described in Fig. 3, the majority of SOs aims to support the users in activity related to the "Maintaining one's health" (d 5702) domain. Accordingly, the need of investigating the ability of these products in supporting a person is raised, in particular concerning the monitoring of the own health and the specific health needs.

To this purpose, it was decided to evaluate the significance assumed by every information provided by SOs in order to monitor the "Body Functions" (BF) defined by the ICF. According to ICF, by the term BF we mean to denote the physiological functions of the body system (including the psychological ones).

This method can be used to assess the SOs potential capabilities to support any person in monitoring its own health condition, whatever it is. In fact, impairments caused by any disease can result in problems, deviations or significant loss in one or more functions of the body.

The summary of the results of the assessment is described in Fig. 4. The graph shows the extent to which the SOs (in terms of percentage) is able to support each body function according to information respectively provided.

The correlations have been classified in three categories, according to their relevance respect to the specific BF:

- information that can be used to measure the functionality in a direct way (in black): the acquisition of such an information allow to directly monitor the loss in a specific BF. For example, the acquisition of *diastolic and systolic blood pressure* allows to determine precisely the state of the "blood pressure functions" (b 420).
- data that can be used to measure the state of the BF in an indirect way (in dark grey). For example, the occurrence of *a fall*, which can be detected thanks to a *fall detector*, can be indicative of impairment of "vestibular functions" (b 235).
- parameters that can be correlated with the state of the considered BF (in light grey): these parameters may provide information about the possible alteration of a certain BF (e.g., the detection of an abnormal *galvanic skin response* can be correlated with a change in the "heart functions" (b 410).

For more details, the correlations identified between the data provided by SOs and body functions are reported in Appendix.

By analyzing the results, it is possible to observe that the about 25% of information provided by SOs can be useful to support the user in maintaining its own weight. A lot of information can be exploited to understand the user emotional state (about 17%) and analyze his/her sleep quality (about 11%). Furthermore, several data related to heart and hematological system functions are captured and analyzed by the majority of SOs (more than 10%).

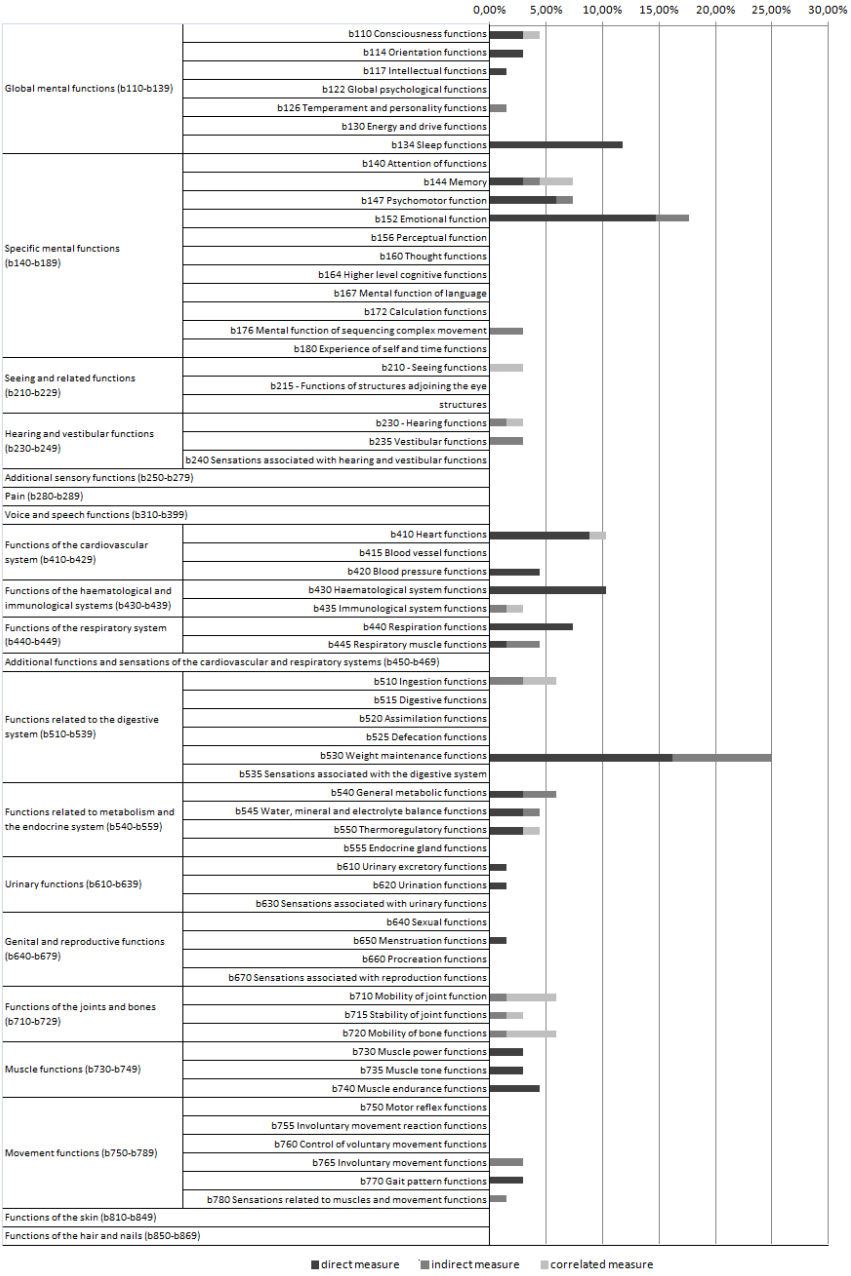

Fig. 4. Potential support for Body Function

4 Conclusions

In an ontological point of view, much evidence show that inclusiveness is a prerequisite of any assistive technology artefacts, aimed at cooperating with people, especially if they have particular needs to face, as the elderly.

To understand if the available products can be considered inclusive and if they effectively match the needs of the elderly, we have started from the analysis of the activities, that it is expected an assistive environment should be able to support.

Using ICF, we have noticed that the available SO are not able to support all the activities, most of all the ones ascribed to the cognitive domain, such as for example, learning and applying knowledge.

It seems that the implementation of more complex software architectures inside the smart objects should be stressed, in order to have a new generation of products, that can be considered more intelligent and intuitive. For example, this can strongly support cognitive processes like work memory, attention and reasoning. This, can be a key issue for assuring the success of the future generation of SO.

Probably, the reason of this defect should be found in the lack of interoperability of the SOs, which is an issue amply treated in literature [11]. In fact, the majority of the SO includes and/or requires specific apps or software to interpret the monitored information and to provide feedbacks to the users. This requirement may represents a limit when these objects have to be interconnected each other, to create an integrated assistive environment targeted on the specific user's needs. Indeed, it is necessary to develop an "intelligent management tool", essential to collect, elaborate and exploit the data generated by several objects.

Currently, it could be said that the SO are not inclusive, because a) they are not able to answer to a specific problem, but just to collect information on some parameters; b) they are not planned to be integrated in more complex systems, that can describe the extended concept of "environment".

Nowadays, the SO can be divided in system-oriented, importunate smartness and people-oriented, empowering smartness [12]. In the first case, smart objects can take certain self-directed actions based on previously collected information, so that the space would be active, in many cases even proactive. In the other case, smart objects empower users to make decisions and take mature and responsible actions.

Through the implementation of the software architectures of the SO, also inside more complex platform, this subdivision can be overcome, creating a new generation of products, that can be context-aware oriented, and finally becoming inclusive.

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Appendix

Table 1. Correlation between Body Functions and parameters provided by SOs

BODY FUNCTIONS \ INFORMATION		Activity pace	Activity speed	Activity time	Activity/Movement	Ankle Brachial Index (ABI)	Arterial oxygen content (CaO2)	Audio	Awoke numbering	Basal Metabolic Rate (BMR)	Bed exit activity	Blood glucose	Blood lactate	Body fat	Body Mass Index (BMI)	Body water	Body weight distribution	Bone mass	Breathing Rate	Calories burned	Carboxyhaemoglobin (COHb)	Cardiac Output (CO)	Core body temperature	Daily Calorie Intake (DCI)	Daily medicines missing	Device status	Diastolic Blood Pressure	Electrocardiography (ECG)	Electroencephalography (EEG)	Electromyography (EMG)	Fall detection	Fork servings frequency	Fork servings interval	Galvanic Skin Response (GSR)	Heart Rate
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b450-b469																																			
b510-b539	b510																														□	□			
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BODY FUNCTIONS \ INFORMATION		Heart Rate Variability	Hematocrit	Hemoglobin	In bed time	Indoor light level	Indoor noise level	Last sip time	Lean mass	Light on/off	Meal duration	Meal time	Metabolic Equivalent Task (MET)	Methaemoglobin (MetHb)	Muscle mass	Open/Close medicines dispenser	Oxygen saturation (SpO2)	Phonocardiogram (PCG)	Position (GPS)	Position change in the bed	R-R Interval	Skin temperature	Sleep quality	Sleep time	Spirogram	Stress level	Systolic Blood Pressure	Urine analysis	VCO2	Video	Visceral fat rating	VO2	VO2 max	Water consumption	Weight
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■ = direct measure □ = indirect measure ▲= correlated measure